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Problems Associated With Operation of Domestic Power Systems

906B0086A Nanjing DIANLI XITONG ZIDONGHUA [AUTOMATION OF ELECTRIC POWER SYSTEMS] in Chinese Vol 14 No 3, May 90 pp 3-18

[Article by Ding Daoqi [0002 6670 7871]: "Ten Problems in Modern Power Grid Operation"; first paragraph is editor's explanation]

[Text] Ding Daoqi, deputy director of the Ministry of Energy Resources Dispatching and Communications Bureau, gave a speech titled "Modern Power Grid Operation and Management" at the 18th National Large Grid Dispatching Experience Exchange Conference on 4 November 1989. The entire speech contained three parts which concerned characteristics of electric power production and modern grid characteristics, 10 problems in modern grid operation that require solutions at present, and work we should be doing. Published here is the second part of his speech (section headings were added at the time of editing). The entire speech was over 30,000 characters long and the Ministry of Energy Resources Dispatching and Communications Bureau has additional data.

Abstract

This article concerns several problems in the two areas of power supply reliability and guaranteeing power quality specifications that have appeared in the development of large power grids in conjunction with the current situation in Chinese power grids and in reference to foreign countries, and it proposes ten problems that should be studied and resolved in operation and management of large grids in China: 1) Electric power system stability and stabilization technologies; 2) generator shaft system torsional vibration problems caused by subsynchronous vibration in large generators (especially large thermal power generators) and coordination of large generators and large grids; 3) power system safety and stability control systems; 4) power system frequency control and economic operation; 5) voltage and reactive power control in power systems; 6) research on power system reliability; 7) power system peak regulation; 8) interaction of nuclear power plants and grids; 9) power system operation and meteorology; 10) construction of a complete applied power grid dispatching automation system and communications monitoring, and control system.

Modern power grids referred to in this article are powerful large grids that are primary grid networks with 500 kV and higher voltage grades, system capacities of several 10,000 MW to 100,000 MW, grid coverage areas which cross provincial, regional, national, and even continental boundaries, 600 MW hydropower and thermal power generators in the grid account for a substantial proportion, and power plants connected to the grid have capacities of several 1,000 MW or even several 10,000 MW. This means that "ultrahigh voltages, long distances, and large capacities" are the main characteristics of large grids. A second characteristic of modern grids is that relations between various grids become increasingly close. The third characteristic is that UHV grids enter urban areas and supply power to urban areas via multiple ring networks. The fourth characteristic is simplification of voltage grades and increased power supply voltages. The fifth is the configuration of an integrated safety and stability control system, a dispatching automation monitoring and control system centered on computers, and a meteorological (thunder and lightning) monitoring system corresponding to the primary system to ensure safe, stable, and economical grid operation and increase the reliability of power supplies. Modern grids also have a relatively complete communications system for each of these systems and for grid operation and management activities. A safety and stability control system, dispatching automation system, and dedicated electric power communications system have become the three pillars which modern grids depend on. A final characteristic of modern grids is that they must have a group of S&T experts with rich practical experience who are adept at applying computers and who can apply systems engineering theory to study, analyze, manage, and command these huge and complex systems. The 10 problems in modern grid operation discussed in this article are set forth on the basis of an understanding of these characteristics of modern grids. Effective solutions to these 10 problems in grid operation and management will help fulfill the basic tasks of the electric power industry, which are to provide "sufficient, reliable, qualified, and inexpensive" power to social production and life.

I. On Power System Stability and Stabilization Technologies

For a long time, the main categories of stability were divided into static stability and transient stability according to the size of system disturbances. The stability of moderate disturbances and periods greater than one to two swing cycles and the effects of automatic control equipment are usually called dynamic stability. However, there is still no clear definition of dynamic stability.

The effects of automatic control equipment are the main goal of research in modern stability theory. The most realistic method based on system disturbances and the effects of automatic control equipment is to classify stability into three time domains. These three time domains are:

1. Transient time domain stability. This mainly refers to the time frame of the first swing cycle (or even longer at two to three swing cycles) that appears in the phase angle of generator rotors after the system suffers a disturbance. It is usually about 1 second (or 2 to 3 seconds). When a short circuit occurs in primary power transmission lines, the action or rejection of main protection action and unsuccessful reclose during this time domain have the greatest effect on stability oscillation.

2. Intermediate time domain stability. This refers to a time frame lasting from more than 2 or 3 seconds to more than 10 seconds which is sustained for several swing cycles to more than 10 swing cycles beginning with the occurrence of the disturbance after a sustained transient time domain. Factors with severe effects on synchronous instability in this time frame are line fault cutout and cut-in, generator and load cutout or cut-in, and other moderate-sized input disturbances that prevent damping of oscillations occurring in a transient time domain and cause them to continue growing. Field regulators, speed regulators, and so on will begin to play a role during this time domain.

3. Static time domain stability. This refers to a time domain longer than an intermediate time domain in which synchronous instability phenomena occur within a time frame of several 10 seconds or infinitely longer time frame. The characteristics of instability phenomena during this time domain are that oscillations are due to intrinsic instability modes (such as field regulators, system parameter resonance, etc.) inherent in the system and are unrelated to the size of the disturbance.

When this sort of transient stability destruction is discovered, it involves the occurrence of output oscillations within a low output range and may even develop into a step-out state when synchronous generators are connected to a power distribution line or power transmission system with a lower voltage grade. Synchronous operation can be restored only after analysis and adopting stabilization measures which are the exact opposite of measures usually adopted. These measures include increasing line reactance or reducing line resistance (that is, reducing the R/X ratio), increasing generator output, reducing generator field current, and so on. This type of phenomenon is called negative damping. Usually, there is insufficient research and concern for this type of phenomenon, which should receive attention.

The adoption of computer technologies and large-scale simulation have enabled the attainment of high precision levels in stability analysis techniques. In analysis of power system stability, equally important analysis methods include generator, control system, and load models (including related parameters). Their numerical models have significant effects on the computed results. For load models, China has continued using Soviet methods of the 1940's for quite some time, using 70 percent constant loads and 30 percent asynchronous generators. We now also make computations using 50 percent for each, so there is a substantial discrepancy. The effects are especially great for the results of transient stability (intermediate time domain) computations. China has also done research on load characteristics. The Beijing Graduate Student Department of North China Electric Power College has made some achievements in this area and hopes to be able to establish load models adapted to actual conditions in each of China's large grids. They must be adapted to the continual expansion of power systems, changes in user structures, improvements in control functions of automatic voltage regulators, steam turbine and water turbine regulators, and so on and use continual measurements to examine and improve stability analysis methods and the precision of computations.

In the area of power system stability control technologies, China and foreign countries are developing toward establishment of comprehensive stability control systems. This so-called comprehensive control is carried out by dividing stability control into three levels:

Level 1. Subsystem integration. This mainly refers to detachment by generator excitation, steam turbine rapid switching, electrical braking, resynchronizing, and re-step-out. These are mainly coordinated according to the time sequence of generators during the step-out process. This part of control is in rather widespread use in China.

Level 2. Local comprehensive control. This mainly involves transmitting a small amount of information within a local system and the use of models to differentiate between achieving generator cutout and load cutout. This is used in all of China's large grids with rather good results.

Level 3. This is comprehensive stability control of an entire power system. Three steps are required to achieve it.

Step 1. Off-line computations are made to coordinate and control each subsystem to meet whole-grid stability requirements. This step can now be achieved.

Step 2. This achieves on-line stability monitoring to establish a decision-making and control system. This may be achieved in foreign countries between 1990 and 1995. The mixed system structure used for power system transient safety analysis studied and developed by Nanjing Automation Institute organically integrates inferences based on simple model rapid expansion equivalent criteria computation methods, complex model integral methods, and knowledge to establish a more realistic planning and decision-making support system that can be used for on-line and off-line transient safety analysis and that can provide effective support for developing prevention and control expert systems. I hope that this research achievement can be turned into forces of production as quickly as possible and used in actual production.

Step 3. The achievement of full-system real-time closed stability control. Inferences in foreign countries indicate that this may be achieved around 1995.

Another question concerning power system stability deserves attention. The previous discussion of transient, static, and dynamic stability in power systems did not include questions of stability related to parameter resonance. In actual power system operation, non-linearity in a power system like transformer saturation, generator saturation, and the effects of non-linear characteristics in

control equipment may cause parameter resonance when the power system is subjected to cyclical interference. Sometimes, the size and speed of divergence of oscillation amplitudes cannot be restrained and can have serious effects on power system stability. So-called low frequency oscillations fall within the scope of parameter resonance.

Research in foreign countries shows that parameter resonance occurs extremely easily under the following conditions:

1. When cyclical changes occur in the bus voltage amplitude and phase angle either singly or simultaneously, parameter resonance can occur.

2. Changes in system load or other system parameters as well as the occurrence of swings or other disturbances in other generators often can cause parameter resonance.

3. Parameter resonance can occur when damping exists in the system if the disturbance is rather strong. In a multiple generator system, each power plant in the system has various different control systems, and parameter resonance phenomena can occur after extremely small interference occurs in a weak damping operation state.

Foreign countries are now doing more research on the question of parameter resonance. China's research in this area can be described as just beginning and it awaits greater intensification.

II. On the Question of Generator Shaft Torsional Vibration Due to Subsynchronous Oscillation in Large Generators, Especially Large Thermal Power Generators, and the Question of Coordinating Large Generators and Large Grids

China has now imported over 20 thermal power generators with a capacity of 300 MW and more from foreign countries, the largest of which is a 600 MW thermal power generator at Yuanbaoshan Power Plant. Active development of research on large generator torsional vibration is an urgent task.

Large steam turbine generators contain some new structural changes. First is a substantial lengthening of their shaft systems. A generator's shaft system includes many components such as an exciter, generator, high-medium-low pressure steam turbine cylinders, back rotor, bearings, and so on which reduce the ratio between the additional length and the radial length of the main shaft, increase the capacity and size of steam cylinder casings, and lengthen steam turbine vanes. This reduces the mechanical vibration frequency of the rotating part of the entire generator to below the synchronous frequency and gives it several subsynchronous intrinsic frequencies. When the generator suffers disturbance from any electrical or mechanical system during operation of when certain types of operational patterns occur in the grid, they can cause subsynchronous oscillation and torsional vibration which can lead to fatigue and destruction of the shaft system.

Subsynchronous oscillations now occur both in power systems with series capacitance compensation and in DC power transmission systems.

For systems with series compensation, when subsynchronous resonance is created by the system's resonant frequency (determined by L and C) and a certain intrinsic frequency of the generator shaft system being near the grid's working frequency, when this asynchronous increased amplitude oscillation is superimposed on the synchronous torque, it can cause shaft system fatigue and destruction and lead to a serious accident involving fracturing of the large shaft.

The mechanism by which subsynchronous oscillations occur in DC power transmission systems is roughly this: When the system is subjected to a certain type of disturbance, a shift occurs in the generator terminal voltage and phase which causes output from the convertor station rectifier transformer and thereby causes a shift in the rectifier ignition angle α and in the DC voltage and current. Under the effects of valve control, when the system's electrical damping coefficient is less than zero and its absolute value is also greater than the mechanical damping coefficient, diffuse torque will occur (this is determined by the product of the voltage and current). When this torque is added to the main shaft of the hydraulic turbine or steam turbine, it is also possible for torsional vibration and destruction of the large shaft to occur.

Research in this area was recently undertaken jointly by the Ministry of Energy Resources Electric Power Dispatching and Communications Bureau and Qinghua University when the Gezhouba-Shanghai +/- 500 kV HVDC was placed into operation. These conclusions were drawn from the preliminary analysis:

1. The risk of the occurrence of subsynchronous oscillation is greater for generators near rectification stations the stronger the relationship of the generators with the DC system.

2. Smooth-wave reactances help restrain changes in DC current, which reduces the probability of the occurrence of subsynchronous oscillations.

3. Compensation for reactive consumption during rectification by reactive compensation capacitances in rectification systems can cause generators to operate below high power factors, which can reduce phase angle swings.

4. There is a great possibility of resonance occurring on the contravariant side during long-distance and heavy load operation.

5. The greater the multiplication factor of a valve control system, the greater the action of negative damping, which makes it easy for subsynchronous oscillation to occur.

6. The situation is more serious in a fixed-power operation pattern than in a fixed-current operation pattern.

These conclusions require further research and analysis and should undergo practical testing in operation.

These three areas should be the focus of research on shaft system torsional vibration:

1. Determination of the intrinsic torsional vibration characteristics of the shaft system (including vanes), including measurement, analysis, and computation of the intrinsic torsional vibration frequency and vibration pattern of all types of generators. China should especially reinforce work in this area because the effects of manufacturing quality, materials quality, and technology lead to substantial divergence in the torsional vibration characteristics of each type of generator shaft system that create problems for research and decision-making in operation departments.

2. Analytical computations for entire generator-power systems, especially dynamic effects and shaft system alternating stresses of each type of disturbance (including mechanical systems) by shaft systems on the electric power system, materials strength, and accumulated fatigue lifespan dissipation, including generator excitation systems and dispatching systems. For DC power transmission systems, models for valve control systems should be established and their characteristics analyzed.

3. Measures for preventing and controlling shaft system torsional vibration (including control and regulation measures), development of shaft system torsional vibration on-line monitoring devices, and so on.

Research in foreign countries on shaft system torsional vibration began in 1970 and the focus of work at present has now shifted to accurate determination of shaft system fatigue lifespan dissipation under actual conditions, perfection of the functions of on-line monitoring devices, and automatic control measures to help control torsional vibration. Work in this area in China began in 1983. Hopefully, research achievements by Qinghua University, Southeast China University, Central China Industrial University, and other institutions will be applied in production practice quickly.

Another major problem linked to the question of large generator shaft system torsional vibration is the question of coordinating large generators with large grids. This is abbreviated as grid-generator coordination. Concretely speaking, it refers to shocks by all types of special operating patterns and accidents on large generators that are necessary to ensure reliable grid operation. As soon as a generator is damaged, however, it often can seriously endanger safe grid operation. For this reason, certain restrictions must be placed on grid operation to protect the generators. Large generators should be able to withstand these shocks and special working conditions, but grid operation also should restrict such shocks and special working conditions or measures should be adopted to reduce damage to generators by these shocks and special working conditions. This is an important aspect of generator-grid coordination.

For dispatching and operation departments, to prevent destruction of shaft systems by torsional vibration, the following abnormal grid operation conditions should be prevented:

1. Generator shaft system torsional vibration during power system accident cutouts.

2. Generator shaft system torsional vibration caused by erroneous generator paralleling.

3. Generator shaft system torsional vibration caused by rapid automatic reclose.

Research has shown that subsynchronous vibration is the most serious abnormal operating condition which causes generator shaft system torsional vibration and affects the fatigue lifespan of shaft systems. Second is three-phase short circuit accidents and unsuccessful reclose when a generator is connected to the system via multiple loops and two-phase short circuit successful reclose abnormal working conditions when a generator is connected to the system via a single loop.

III. Power System Accident Prevention Devices and the Question of Safety and Stability Control Systems in Electric Power Systems

After an accident occurs in a grid (called a primary accident), it is possible that simple cutout of the broken component can place excessive loads on other components or cause voltage drops and frequency reductions, and even destruction of stability. This type of expanding accident is called a secondary accident. Secondary accidents cannot be handled by relying on single component protection. Instead, new measures must be adopted to prevent accidents from expanding. This is the so-called safety and stability control system problem of electric power systems.

There are many examples of the occurrence of primary accidents that expand into secondary accidents and cause grid disintegration.

The occurrence of these major accidents has attracted the concern of electric power departments in all countries for the development of safety and stability control systems. China has also begun working in this area in recent years but it should be said that our attention is insufficient.

Integrating trends in China and foreign countries, electric power system safety and stability control technologies should focus on two aspects:

1. Development from single control devices or local control systems in a decentralized configuration to control systems that can take regional or full-system conditions into consideration.

2. Development from control devices with relatively simple functions and composed of logic circuits to control systems with full functions and accurate forecast

functions that are implemented via microcomputers and communications technologies.

Electric power system safety and stability control systems must achieve the following functions:

1. High-speed breakdown diagnosis and cutout.

2. Capability of preventing expansion of accidents.

3. Capability of restoring normal system operation quickly.

When designing system safety and stability control systems, full attention must be given to the effects arising from changes in grid operation patterns due to control to facilitate correct control of transition to a normal grid operation pattern. Special consideration must be given to changes in the following seven areas:

1. Changes in neutral point grounding;

2. Transient stability limits;

3. Short circuit current and switch breaking capacity;

4. Large generator torsional vibration torque;

5. Permissible frequency variation limits of large generators;

6. Overload capacity of lines, transformers, and other components;

7. Reactive voltage equilibrium and so on.

Research and application of system safety and stability control devices in China's grids has begun to move from the simple to the complex. Low-generator load reduction, oscillating generator cutout, oscillation detachment, distant generator cutout or load cutout, electrical control, steam generator valve fast closure, and other things play positive roles in maintaining local and regional safety and stability in grids. Power system stabilizers (PSS) developed by some institutions of higher education, scientific research departments, and electric power departments are now being used in the Northeast China, Central China, Northwest China, and other grids and they are playing a positive role in improving system damping and controlling low-frequency oscillations.

In foreign countries, PSS is now in common use as the primary means for stable generator operation. Practice has shown that PSS produces rather good results in improving power system stability. Most detection signals used in PSS employ ΔP control patterns with strong interference resistance properties that are easy to detect, but they also use a combined arrangement for detecting ΔP and $\Delta\omega$ signals. This type of arrangement can prevent erroneous action of load tracking protection in thermal power generators. The widespread use of PSS also poses a new problem, which is that the continual increase in the number of generators fitted with PSS can create mutual interference among PSS in several generators and other problems. Thus, we must do research on optimum PSS distribution programs and develop and study designs for optimum PSS parameters in multiple generator systems.

China is now in the process of developing regional stability control devices. The West Liaoning Grid stability control system developed jointly by the Northeast China Power Management Bureau's Electric Power Dispatching Bureau and Nanjing Automation Institute includes a primary device and four secondary devices for the first stage of the project that were installed, respectively, at the Jingzhou Dongjia 500 kV transformer station, Yuanbaoshan and Jingzhou Power Plants, Haicheng and Liaoyang 500 kV transformer stations, and other plants and stations. Each device is composed of microcomputers and channels used to transmit information to form centralized control systems. These systems are mainly used to improve transient stability in the West Liaoning Grid and to prevent overloading of lines and other equipment. Hopefully, these devices will be placed into grid operation soon.

Because the region over which a power system is distributed is very broad and transient process changes occur very quickly, the state of the entire system must be collected within an extremely short time to achieve full-system centralized control. This is not just technically difficult. It is also rather hard to expand. Safety and reliability are not easily guaranteed, so this is not the most rational way. Thus, all countries are now depending on developing stratified control systems in which complex dynamic systems are divided into several subsystems. Partial control devices are installed for each subsystem and coordination and control devices are installed for the entire system to coordinate the actions of each local control device. The partial control devices are also composed of several basic controllers. This sort of stratified control system in which each part can function with relative independence and achieve identical coordination of the whole system is the direction of development at the present time. Stratified control systems in the Soviet Union, for example, have a basic level that is an automatic emergency control center composed of microcomputers that includes local control devices and adjustment devices. The second level is regional coordination EMS and SCADA coordination procedure controllers. The highest level is the All-Soviet Grid Dispatching Center's emergency control system.

IV. The Question of Power System Frequency Regulation and Economic Dispatching

The first thing concerning this question is the need to unify ideology and clarify the status of grid frequency regulation and economic operation in grid operation and management work. This is stated from the perspective of managing modernized grids.

In the area of frequency regulation and economic dispatching, we should focus on these five things at the present time:

1. Perfect AGC and EDC coordination and control systems.

Importing work to automate dispatching in four large grids has now been basically completed and they have been placed into operation. The urgent task at present is to take full advantage of AGC/EDC functions. Four things must be done to achieve this.

1) Grid and provincial bureaus must implement work to perfect basic automation of frequency regulation generators well to meet the requirements of frequency regulation. Provincial dispatching should arrange and implement basic work for automation of generators involved in frequency regulation according to grid dispatching requirements.

2) In the current situation of substantial electric power shortages, grid and provincial dispatching should actively create the conditions and strive to place AGC into operation as much as possible. During valleys, holidays, and so on when the system has an adjustment capacity, they should take advantage of AGC functions.

3) Active power distribution should implement EDC according to the equivalent micro-increment method corrected for grid losses. The equivalent micro-increment characteristics of each power plant generator and system should be implemented in relevant bureaus and plants and completed according to schedule, and adjustments should be carried out according to actual conditions to ensure the benefits of EDC.

4) Grid dispatching should organize provincial dispatching for consultation on the corresponding economic compensation measures after AGC/EDC is implemented. State dispatching should be responsible for organizing and carrying out this work. Only in this way is it possible to ensure that the advantages of AGC/EDC are obtained both technically and economically.

2. Integrated grids in which provinces are the main force should perfect control systems which control integrated line loads according to frequency shifts (Δf) and power shifts (Δp).

3. We should continually summarize experiences with AGC/EDC. The primary economic benefits of dispatching automation systems engineering are realized through AGC/EDC.

4. Reinforce research and applications of integrated hydropower and thermal power dispatching work, including economic operation of different hydropower stations (cascade power stations) in the same water system and comprehensive economic load distribution for hydropower stations and thermal power plants.

China's northeast power system was one of the first grids to achieve economic dispatching, and it can save about 1 percent of fuel annually. In large power systems, large pit-mouth power plants distant from load centers consume more coal than medium-sized and small power plants located near load centers, but grid losses are higher. To derive the maximum benefits after correcting their micro-incremental increases for grid loss factors, the economic benefits in the Northeast China Grid could increase an additional 0.3 to 0.4 percent. Hydropower and thermal power matched dispatching can also expand benefits by 0.2 percent. Indications from the Northeast China Grid show that, although the northeast power system has energy shortages, it has achieved maximum benefits from AGC/EDC and can still carry out economic dispatching 12 to 16 hours a day.

5. We must try as much as possible to perfect two things in the area of AGC/EDC operation technologies:

1) Study and develop economic dispatching procedures that take safety restriction conditions into account and implement them as quickly as possible;

2) Perfect joint hydropower and thermal power optimum dispatching procedures adapted to the reservoir and water system characteristics of a particular system and apply them.

China's Qinghua University, Hehai University, and other institutions of higher education have made definite achievements in these two areas but they have not yet been perfected and applied.

V. On Power System Voltage and Reactive Power Control

Problems in this area are becoming increasingly acute due to the development of modern grids. The main reasons are:

1. Large capacity generators are connected directly to UHV grids, so the UHV grids have no surplus power;

2. The rapid development of urban power supply grids and increasing numbers of cables have increased the charging capacitance power;

3. When a power system is in an abnormal operational state, taking large generators or UHV power transmission lines out of operation causes overloading of some of the UHV lines and there is a serious shortage of reactive output;

4. Grids are configured with inadequate reactive equipment during the development process. Local regions have even more obviously inadequate reactive power after load increases, with the result that local grids operate at low voltage levels for long periods.

These factors have serious effects on safe and economical grid operation. These effects are manifested mainly in:

1. Effects on the voltage quality for subscribers;

2. Effects on the power transmission capacity of power transmission systems;

3. Effects on power losses in grids;

4. Effects on abnormal system voltage rises and damage equipment and expand accidents;

5. Effects on voltage stability, even to the point of causing voltage breakdowns and grid disintegration.

These effects must be considered from an integrated perspective of assuring system power quality and safe, stable, and economical system operation for comprehensive coordination and control of grid voltage and reactive power. Foreign countries have obtained excellent results using this type of coordination and control. The principles of coordination and control require consideration of the following in determining a specific voltage level:

1. Reactive power regional equilibrium;

2. Reactive power that tries to reduce transmission between various voltage grades;

3. Implementing comprehensive coordination according to stratified control patterns.

Overall, a stratified control pattern involves first using off-line calculations for the lowest level to determine bus voltage and reactive power baseline values for each power transformation station and then carrying out adjustment and control using the voltage adjustment devices and phase adjustment devices for each power transformation station. The second level involves using the voltage reactive power distribution situation to divide certain power stations and power transformation stations into a power supply region and having the dispatching center for this region collect information on current, voltages, and so on for each power station and power transformation station in the region and use a command pattern after logical diagnosis by local devices to transmit it to the voltage regulation devices at each station in order to maintain a standard voltage for each power supply station. The third level is the central control level. It is responsible for coordination and control of work to make reactive adjustments in voltages in each of the regional control centers.

China is just now beginning to give attention to coordination and control of voltage and reactive power and our progress is not great. Objectively speaking, the main thing is the lack of equipment and measures for voltage and reactive power adjustment. We should begin solving this by working in the areas of grid equipment plans and operational management.

These measures are usually adopted in the area of equipment planning:

1. Design and manufacturing departments should consider expanding the capacity of large generators for phase retarding and phase advancing operation when designing and manufacturing large generators. The former is mainly restricted by rotor coil temperature rises while the latter is mainly restricted by stator end temperature rises and static stability limits. They should receive comprehensive consideration during designing. During phase advancing operation, there should be reliable ways to reduce in-plant voltages and auxiliary generator voltages.

2. Install adequate phase regulation equipment. This mainly includes rational configuration of shunt capacitors (SC) and shunt resistors (ShR). In particular, control devices capable of rapid cut-in and cutout should be added for breakdown periods. Special attention should be given during planning and design to voltage instability phenomena that arise when large capacitance SC are connected at the receiving end of long-distance large capacitance load lines.

3. Consideration should be given to adopting multi-loop and ring systems as network structures to improve receiving end voltage and current characteristics.

4. Install synchronous phase regulators or static reactive compensators (SVC) at the receiving end. This can increase the capacity for maintaining receiving end voltages. Conveniently, synchronous phase regulators have prominent advantages in the areas of maintaining voltages and improving system static stability but they do not aid dynamic stability during grid dynamic processes. SVC have a fast response speed and are easy to operate and maintain, and they can increase system damping. We should try to extend their use in the future.

5. Rationally adopt transformers with load regulation taps.

The following are the primary measures for reactive voltage control in the area of grid operation:

1. Adopt rational operation patterns and immediate cut-in and cutout voltage and reactive power adjustment equipment. The concern here is that SC should be cut in immediately when there are abrupt increases in loads. As soon as the voltage drops, cutting in additional SC will have limited effects because the reactive capacity of SC is directly proportional to the voltage squared.

2. Adopt emergency load control. When the voltage drops to a specific level, part of the load should be immediately cut out.

3. Actively create the conditions for good organization of large synchronous generator phase advancing operation experiment work and gradually extend it.

Another question regarding voltage and reactive power control that deserves attention is the problem of voltage stability and voltage collapse. Voltage instability is not as well understood as power angle δ instability. Moreover, destruction of voltage stability is sometimes mistakenly viewed as the same thing as static destruction. There is still no clear definition of voltage instability at the present time. Most research methods for voltage instability are concerned only with the special area of voltage collapse, but there is no clear concept of the entire process.

Actually, there are many examples of voltage collapse caused by voltage instability in foreign countries that has caused large-area power outage accidents. A voltage collapse accident in the Wuhan and Huangshi regions in the Central China Grid on 27 July 1972 caused complete disintegration in the receiving end system. A voltage collapse accident in the Dalian area in the Northeast China Grid on 12 July 1973 caused a power outage in the entire Dalian region. System accidents in the United States in the New York Electric Power Company on 22 September 1970 and 13 July 1977, a system accident in France on 19 December 1978, system accidents in northern Belgium on 4 August 1982 and in Japan on 23 July 1987, and others were caused by voltage instability.

After analytical research and practical examination of system accidents, an obvious distinction can be made between voltage stability and static stability as reflected mainly in:

1. The conditions for maintaining stability are different:

The conditions of voltage stability are that voltage swings at the load end do not expand after a minor disturbance;

The conditions of static stability are that phase difference swings among synchronous generators do not expand after a minor disturbance.

2. The main causes of stability destruction are different:

Destruction of voltage stability is due to reduced voltage sustaining capabilities (dP/dV, dQ/dV) at the load end;

Destruction of static stability is due to reduced synchronous power (dP/dδ) among synchronous generators.

3. The grid structures which cause destruction of stability are different:

Voltage stability destruction mainly occurs in regions with large load concentrations and constant power characteristics and in which the power source capacity of the region is also small so that it must be transmitted into the power system from distant power sources;

Static stability destruction mainly occurs in generators and pumped-storage generators connected to grids via parallel long-distance power transmission lines in systems that have rather substantial synchronous generator phase differences.

To ensure voltage stability, analysis and computations are often used to determine the minimum allowable operating voltage in certain central points in the grid. This is termed the critical voltage. However, the confidence level and accuracy of these computations and analysis depend entirely on research and analysis of power transmission system characteristics, generator characteristics, load characteristics, and compensation device characteristics. This causes many problems for voltage stability analysis. Scientific research departments and production and operation departments must integrate closely to be able to do this work smoothly.

As for preventing voltage destabilization and collapse, from the perspective of grid operation, these four main things should be handled well:

1. Maintaining load bus voltage variation curves far above critical values;

2. Adopting limited power transmission if there are inadequate reactive power sources, starting up reserve generators, and so on;

3. Operating generators in a moderate or relatively low excitation state to provide sufficient "rotating" reactive reserves;

4. Under extreme conditions, shutting down automatic regulation functions in automatic voltage regulation transformers (in a situation of reactive shortages and very low voltages, automatic regulation by automatic voltage regulation transformers can cause voltage collapses) and cutting out loads.

As for voltage stability analysis methods, China and most foreign countries rely on conventional current and stability procedures to analyze voltage stability losses. Solving this problem requires rich system operating experience and systematic knowledge, and much work remains to be done concerning further analysis methods.

VI. On the Question of Power System Reliability Research

The main factors which affect power system reliability include:

1. Available reserve capacity and fuel supply levels;

2. Primary junction lines which form the system's main framework;

3. The abundance of reserves in power supply and power distribution grids;

4. Technical characteristics and indices of power system equipment reliability;

5. Controllability of power system production processes and operation patterns;

6. Functions and development levels of dispatching automation systems;

7. Overall levels of power system and power equipment "controllability" under normal and accident conditions.

Because the factors which affect reliability are so complex, reliability involves complex systems engineering. Research on reliability is usually done by dividing a power system into three parts:

1. The reliability of power generation systems

This mainly refers to the capacity of power plants for maintaining continuous power equilibrium;

2. Reliability of primary grids

This mainly involves research on the stability of parallel operation of synchronous generators and the transmission capacity of power transmission networks;

3. Reliability of power distribution grids

This mainly involves research on the ability of power distribution grids to achieve uninterrupted power supplies to each user and groups of users.

Power industry departments should develop reliability management in these three areas. To do good work in these areas, we should at least clarify the responsibilities of planning and design departments and dispatching and operation departments in the area of reliability management.

The main duties of planning and design departments are:

1. Determining power generation capacity configurations and primary grid structures;

2. Optimizing integration of reserve capacity and primary connecting line transmission capacity;

3. Selection of large power plant and transformer station main connections;

4. Dispatching automation systems, accident prevention and control systems, and configuration of the corresponding channels.

Power dispatching, which is the grid operation command department, cannot and should not fail to coordinate with and assist planning and design departments in doing this work well.

The primary duties of dispatching operation departments in the area of reliability management are:

1. Determining the reliability of all types of operation patterns.

Reliability management for power supplies to individual subscribers or groups of subscribers should be determined by dispatching for the next lowest level. The levels at which the reliability of power supplies at primary grid load junctions and grid operation patterns are guaranteed is completed by dispatching at the highest level in the grid.

2. Applying reliability theory to direct grid operation in normal, overhauling, and post-accident grid operation patterns.

This mainly refers to determining operation patterns according to reliability conditions and making "re-optimization" corrections for the operation pattern after calculating stability conditions. Moreover, reliability calculations must be made for planning overhauls and arranging operation patterns, and a decision must be made as to whether or not unplanned overhauls are to be permitted in overhaul arrangements.

3. Establish special groups or specialized personnel to carry out reliability management in operation pattern groups at all dispatching levels to complete this work.

VII. On the Question of Power System Peak Regulation

In modern grid operation, as load structures and the proportion of power used in modern life have increased, daily load rates have gradually decreased and the question of peak regulation has become increasingly acute. The quality of power is also affected by peak regulation capacities. All of China's large grids, especially systems with a large proportion of hydropower, often use hydropower to carry basic loads and thermal power plants for peak regulation during wet seasons to avoid dumping water or reduce the amount of water dumped. During periods of light loads, limited thermal power peak regulation capacity often forces grids into high frequency operation which endangers grid safety and economy.

To solve peak regulation problems, we should do the following work now well:

1. Strive to develop hydropower stations and pumped-storage power stations with regulation capabilities and put several large peak regulation and gas-fired turbine generators into operation;

2. Begin with power station designs to clarify low load capabilities according to primary and auxiliary generator conditions and thermal control levels;

3. Require adoption of measures in generator and boiler designs and determine minimum output of generators with a prerequisite of not using oil to assist combustion;

4. Have production technology departments meet with dispatching departments to organize low output experiments with existing thermal power generators and adopt the corresponding measures to formulate regulations for minimum generator output;

5. Gain an understanding of the startup and shutdown characteristics of thermal power generators and allow one startup and shutdown per day for 50 and 100 MW thermal power generators.

The Japan Electric Power Company has formulated low-load restrictions for all its thermal power generators and prepared clear regulations concerning the size of the minimum load that those generators can carry and how long they are permitted to operate at low loads. For thermal power generators used in daily peak regulation, because of the frequent startups and shutdowns and low annual utilization rates, generators should be chosen which have small startup losses and short startup times, and which track load changes quickly.

6. Another question related to peak regulation is the need to actively undertake research on load control

technologies to increase load management capabilities. Using differences in load properties and technical and economic (mainly electricity price) measures to deal with controllable load power-use time periods can enable peak regulation and reduce reserve capacity in the system. Load control is another important technical measure for shortening the time period required to deal with grid accidents, increase the speed of dealing with accidents, and restore normal operation as quickly as possible.

We have discussed several peak regulation methods above. Actually, the most effective method for dealing with peak regulation problems is to develop hydropower. For the past 20 years, because Western Europe, the United States, and Japan have fully developed nearly all their developable hydropower, they have usually built pumped-storage power stations to handle peaks and they have expanded and added generators to hydropower stations with small initial design capacities to increase their peak regulation capabilities.

Based on experiences and lessons in Western developed nations, China should give full attention to focusing on peak regulation and not on power output in hydropower station construction. The yearly utilization times of most hydropower stations already built in China exceeded 4,500 hours, which obviously is a high figure. If we fail to give them our attention now, expansion of grids and more acute peak regulation problems will force us to take the old path of the Western nations in again carrying out technical transformation of our existing hydropower stations. This is particularly true as China completes and places into operation nuclear power plants because the peak regulation question will have to be solved rather quickly.

VIII. On the Question of Nuclear Power Plants and Their Mutual Effects on Grids

Developing nuclear power is an important way for the world's electric power industry to solve its energy resource shortages.

China plans to complete 6,000 MW of nuclear power generators by the year 2000. Both the Qinshan and Daya Bay Nuclear Power Plants now under construction have pressurized-water reactors [PWR].

To adapt to several new problems in operation that will appear once nuclear power is connected grids, we should begin making ideological and technical preparations now. Below, I will discuss several points from the perspective of demands placed on grids by nuclear power plants:

1. Grids must create stable conditions for the startup of nuclear power plants. The first thing is to prevent grid operation at reduced and increased frequencies.

Frequency reductions reduce the power of reactor auxiliary equipment. This is especially true for PWR. A reduction in system frequency will reduce the power of primary cooling pumps, which will cause reactors to absorb heat, reduce power, and lead to expansion of accidents (core overheating). Similarly, increased frequency operation cannot be permitted. Most current regulations state that when the generator frequency drops below 48.5 Hz or rises to 50.88 Hz (boiler water reactors BWR) and 51.25 Hz (PWR), reactor operation should automatically be shut down.

2. Grids must provide nuclear power plants with reliable sources of power for in-plant use to avoid detached operation of a nuclear power plant and grid.

A series of chain reaction operations must be carried out in the relevant reactors for restarting after forced detachment and generator shutdown at a nuclear power plant. This takes a longer period of time than is necessary for conventional boiler ignition and startup. This is particularly true for the chain reaction in a reactor because the Xe concentrations generated increase after the generators are shut down, delaying the critical reaction of a reactor. Thus, attention should be given to immediately providing external power sources after a nuclear power plant is detached.

3. Pumped-storage power stations should be built simultaneously with nuclear power plants to solve the peak regulation problem.

To prevent bending of the fuel rods in a nuclear power plant due to heating, loads should not be changed frequently, so they are usually allowed to operate carrying basic loads. The speed must be strictly controlled when output is adjusted.

For nuclear power plants with either PWR or BWR reactor types, the speed of load changes is different. Control rod adjustments are not allowed in BWR within an output range of 65 to 100 percent. Instead, changes in the speed of recirculation pumps are made to change recirculation flow rates so that they change at a tracking speed of 30 percent per minute. PWR reactors use control rods to control output and the drive speed of the regulation control rods determines the speed of changes. They can carry out +/- 5 percent/second sloped and +/- 10 percent/second stepped load changes.

Special attention must be given to the stability question when pumped-storage power stations and nuclear power plants are operating in the same grid. The reason is that an increase in the power angle δ of thermal power and nuclear power generators and water pumps during nighttime water pumping operations will reduce overall system stability.

IX. On the Question of Power System Operation and Meteorology

All modern grids in foreign countries have established a complete meteorological monitoring system in their dispatching and control centers. Meteorological cloud

charts transmitted by meteorological satellites and forecasts by meteorological departments are used for comprehensive monitoring of meteorological conditions in the region covered by the grid, and they take immediate steps for power system operation and accident forecasts based on meteorological conditions to enable safer and more stable grid operation levels.

Power systems are significantly affected by changes in precipitation, air temperature, lightning, wind and snow, major frosts, and other meteorological conditions. After dispatching departments collect meteorological information based on meteorological monitoring systems, they should immediately make the necessary system adjustments and operations based on meteorological reports such as the intensity and range of lightning and its direction and speed of movement, direction of typhoon advances, and so on. These adjustments and operations generally have the following content:

1. Increased power generation operating reserves. Good preparations must be made to increase operating reserves. Hydropower generators can be paralleled in a few seconds to 10 seconds but thermal power generators take longer to parallel, so good preparations must be made in advance. When necessary, grids are paralleled for low-load operation in preparation for use during accidents as needed.

2. Projects for shutdown and power outage operations such as overhauls of lines, primary transformers, and the related relay protection and communications equipment should try to restore this equipment to operation.

3. Coastal areas with salt hazards and certain regions which have heavy frosts should operate at reduced voltages to prevent porcelain insulator flash-over accidents.

Coastal regions often face salt hazards from approaching typhoons and winter monsoons. Heavy spring and summer frosts are also common in some areas. This often causes porcelain insulator flash-overs which trip multi-loop UHV lines and can even expand into large-area power outage accidents. The most effective way to prevent or reduce such accidents is to operate grids at reduced voltages. The extent of the reduction is generally controlled at about 5 percent of the rated voltage according to the severity of the meteorological conditions at the time. In the Gezhouba-Shanghai +/- 500 kV DC power transmission system, for example, the minimum permissible voltage reduction is operation at 70 percent.

Tripping of multi-loop UHV lines has occurred frequently in China during major frosts over the past several years. Dispatching and operation departments are responsible for immediately adopting measures for reduced voltage operation to prevent the expansion of accidents. Attention also must be given to:

1. Under adverse meteorological conditions, efforts must be made to stop using automatic reclose on power transmission lines. After lines are tripped, efforts should be made to prevent forced power transmission.

2. Immediate adjustments in current and changes in operating patterns must be made according to meteorological conditions.

3. When forecasts and warnings are issued for typhoons, lightning, rain, snow, frost, and other hazards, dispatching units should immediately notify all relevant units to enable them to move into a warning operation state immediately.

Practice in foreign countries has shown that an advanced meteorological monitoring system plays an enormous role in guaranteeing safe grid operation and provides rather high social and economic benefits.

In the future, the Ministry of Energy Resources should establish meteorological monitoring systems in grid and bureau dispatching departments in a planned manner in stages and groups. The Central China Grid has already installed a lightning monitoring system in its Central Dispatching Department and obtained definite benefits.

The State Electric Power Dispatching Center should cooperate with the State Meteorological Bureau and Ministry of Water Resources' Water Dispatching Center to establish a complete national meteorological monitoring center in the State Dispatching Center to provide the necessary means for state dispatching to provide better guidance for safe operation in all major grids.

X. On the Question of Building a Complete and Applied Grid Dispatching Automation System and Communications and Monitoring System

The development of grid dispatching automation system technologies began in the mid-1960's and now has a history of about 25 years. Present dispatching automation systems have developed an energy management system (EMS) that includes data collection and control (SCADA), automated power generation control (AGC), economic dispatching operation (EDC), grid static safety analysis (SA), and dispatcher training simulation (DTS). The scope and functions of this system are continually developing.

Since the first set was placed into operation in the East China Grid in the late 1970's, Chinese grid dispatching automation systems have made enormous advances. All grids are now trying to establish relatively complete EMS systems.

The four big North China, Northeast China, Central China, and East China grids imported four EMS systems developed by WSL in England that were placed into operation in 1988 and 1989. The mainframe configuration of this system uses a mainframe-lead computer stratified structural arrangement to handle large numbers of computations and process large numbers of interrupts. To reinforce reliability, the mainframe and lead computers have 100 percent redundancy. This configuration pattern is still the main trend in the present

EMS system configuration. The support software is the HABITAT software package developed by the United States' ECSA Company. Users indicate that this support software has rather strong functions and is convenient to use, but it depends too much on the hardware system and is particularly dependent on the type of display. If a user wants to add another type of display, it cannot be supported by the current HABITAT.

China's dispatching automation system projects have now been completed for five grid dispatching, 23 provincial dispatching, and nearly 100 dispatching departments and is now developing toward county-level dispatching. It can be said that the situation is quite good and that it is already playing an active role, manifested mainly in:

1. Providing dispatchers with a new means of visual and effective comprehensive monitoring of grid operation conditions;

2. Immediately providing dispatchers with operating conditions in accident situations and providing effective information for decision-making and guidance, which has greatly reduced accident handling times;

3. Monitoring whole-grid power generation and power use conditions, improving the quality of power, promoting planned power use, and reducing useless shutdowns and power restrictions;

4. Application of EDC has improved the economy of grid operation.

It must be noted, however, that there are several problems in China's work to build EMS that deserve our attention. These problems have already seriously affected EMS system benefits. These problems include:

1. Superficial pursuit of large scales, many functions, and high investments in equipment and new construction that have not produced benefits for long periods;

2. Basic automation construction is not carried out simultaneously with dispatching center automation system construction, creating an "advanced brain with four dead limbs" that cannot play its role;

3. The development schedule for some systems is too long and they cannot be placed into operation for long periods, which wastes manpower and finances;

4. Without unified planning, moving ahead with trial manufacture of each type of equipment to form complex interfaces or even an inability to interface them will forestall system benefits.

The existence of these problems has prevented application of EMS systems. For this reason, the Ministry of Energy Resources issued a special document in 1988 that proposed basic requirements for application. The gratifying thing is that they passed examination organized by the ministry on 9 April 1989. The local dispatching automation system in the Nanjing Power Supply Bureau has met the application requirements set forth by the ministry to become the first in China to apply a dispatching automation system.

It should be stated that the Ministry of Energy Resources application standard requirements are the most preliminary and most basic requirements for an EMS system.

However, we still have much work to do to establish a complete EMS system with full analysis, decision-making, processing capabilities.

The main things are:

1. We must further lighten the burden on dispatchers and establish advanced, applied, and convenient man-machine linkage systems.

Existing EMS systems are often limited by their displays. Much data and computed results must be displayed in tables which are not very visual, so dispatchers are unwilling to use them. Now, displays are commonly moving toward high densities and full-images with a substantial improvement in performance. Such displays make wide use of technologies developed for graphic work stations use as panoramic shifting, enlargement and reduction, multiple window functions, three-dimensional graphic display functions, and so on. Using large amounts of digital simulation graphics which can include results of grid analysis software computations instead of tables makes it extremely convenient to visualize things.

2. We should expand applied software from static safety analysis to the realm of dynamic safety analysis.

At present, the applied software in EMS systems is still restricted to static analysis, whereas the most serious problems which threaten grid safety are often transient and dynamic stability problems. This is especially true for the rather weak situation in China's grid structures, where dynamic safety analysis is even more important. The key to solving this problem is finding a rapid transient safety algorithm. Thus, to satisfy safety control requirements in power systems, people have always tried to find a rapid stability estimation method to meet real-time requirements. To date, those with definite research achievements include the Liapunov method and the model identification method. There are no examples, however, of actual application. A transient stability analysis program recently developed using and expanding on the equivalent method by Dr Bi Yusheng [5643 4416 0524] of Nanjing Automation Institute has encouraging speed and confidence levels and there is hope that after the addition of compound asymmetrical breakdown analysis computations this achievement will be quickly applied in the realm of dynamic safety analysis.

3. There should be further improvements in existing applied software. There should be additional improvements in the areas of simplicity and convenience, reliability, and applicability.

For example, there is no satisfactory way to identify topological errors. Its use to correct control switchover operations analysis is immature. The method of using busses to predict loads is not reliable. Certain aspects of economic analysis lack applicability, especially generator startup and shutdown plans, optimum currents, and so on. Moreover, the question of dealing with optimization of system measurements in state estimating and identification is one problem that urgently demands solution.

4. To reduce the burden on dispatchers and improve decision-making levels, we should actively input new intelligent and expert systems technologies in the applied software.

In existing applied software, dispatchers must draw their own conclusions from a huge torrent of data but they often discover that they lack certain information they would like to know. Under the influence of these highly intense psychological factors, it is extremely hard even for experienced dispatchers to remain calm and handle accidents without making mistakes. Moreover, many intractable problems are being encountered in relying only on numerical analysis methods for power system safety control and economic operation. In much work, such as the question of how to guide dispatchers in effectively preparing data when there are problems in selecting the amount of control and limits are hard to quantify, they still must rely on expert experience. An artificial intelligence and expert system should be established for this purpose to help dispatchers make decisions and handle problems. R&D in this area has attracted the attention of several experts in China. Nanjing Automation Institute, Xi'an Jiaotong University, Qinghua University, and other institutions have made preliminary achievements in this area. What deserves special mention is that the Gansu Grid Auxiliary Dispatching Expert System jointly developed by Gansu Provincial Electric Power Bureau and Gansu Industrial University is now being tested in actual grid operation.

The questions set forth above are proposed only from the perspective of their use by grid dispatching and operation personnel. Several questions regarding EMS systems (including RTU and so on) such as support software, operating systems, software standardization, and distributive systems which use high-performance microcomputers, work stations, and local networks as a foundation, the ideology of open system integration (OSI), and other problems have quite a few new technical problems that must be studied and resolved.

Finally, I will again discuss the question of establishing a power communications network monitoring system. Power system communications has now become an integral part of modern grids. Without it, grid safety and stability control systems and dispatching automation systems cannot be implemented and it is even less possible to achieve normal grid operation and management. To date, China's power system has completed nearly 18,000 kilometers of microwave circuits and about 600 stations. We have completed nearly 260,000 voice circuit kilometers of electric power carrier wave circuits, 180,000 gates in repeater capacity, six satellite earth stations, and 20 fiber-optic communications circuits covering nearly 250 kilometers. We also have scattering and coaxial cable carrier waves, mobile communications, and so on. The overall scale and equipment levels in our communications network are at the forefront of dedicated communications networks for all industries in China. Like power grids which must establish EMS systems, installing a communications and monitoring system adapted to communications network operation and management requirements and composed of increasingly enormous, criss-crossing, and multiple communications patterns is an extremely urgent task.

Foreign countries began studying and developing communications network monitoring systems back in the 1960's. The Tokyo Electric Power Company placed a second-generation communications network monitoring system into formal operation on 1 April 1990 to replace the first-generation communications network monitoring system that had been in use for nearly 20 years. This new system cost 4 billion Japanese yen (almost US$30 million) and can implement comprehensive monitoring and control of 7GC FDM and 2GC PCM microwave communications systems, fiber-optic communications systems, and electric carrier wave and communications cable systems. Its main functions are operational monitoring, computation, statistical analysis, stack control, and network-input management for communications networks. It has played a significant role in guaranteeing the reliability of communications network operation, traffic volume statistics, dispatching commands, and maintenance and overhauling.

It is extremely necessary and urgent that China develop a communications network monitoring and control system. However, it cannot be detached from China's national conditions in a blind pursuit of high performance and high indices. This system should be an advanced and applied system and its main functions should be: real-time monitoring, data collection, breakdown statistic processing, performance analysis, route control, traffic volume statistics, and so on.

The structure of the communications monitoring system should be similar to a dispatching automation system and it should be configured according to the principle of stratified management. Based on actualities in China, it should be configured in three levels:

1. Level 1: Ministry of Energy Resources Centralized Monitoring Center;

2. Level 2: Grid and bureau monitoring centers;

3. Level 3: Provincial bureau monitoring centers.

To make good preparations for building the communications monitoring system, we should prepare good plans which take all aspects into consideration, do good feasibility analysis, and implement them in stages. We should try during the Eighth 5-Year Plan to complete

construction first of communications monitoring systems in the five large North China, Northeast China, East China, Central China, and Southwest China grids, and it is possible to achieve monitoring and control of China's primary microwave communications trunkline networks. It would be best to work first on a system using mainly high-performance microcomputers with additional trial points where we can gain experience and then extend it.

Of course, besides the 10 problems discussed above, there are several other important problems related to actualities in the development of China's grids that should be studied and resolved. For example, we lack experience in operating the +/- 500 kV Gezhouba-Shanghai DC power transmission system that has just gone into operation, research on DC power transmission system regulation patterns and regulation characteristics, research on using DC power regulation to improve grid reliability, research on the dynamic characteristics and reliability questions for AC/DC interconnection systems, and so on which are urgently in need of study and resolution. The Academy of Electric Sciences, Zhejiang University, Zhejiang Provincial Electric Power Bureau, and other units have done a great deal of work in this area and made many achievements. There should be further intensification in the future to guide safe operation of DC power transmission systems.

Layout, Operation of Relay Protection of Major Grids

Northeast China

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[Article by Ji Youdang [0370 2589 8093] of the Control and Communications Office of Northeast China Power Bureau: "Layout and Operation of Relay Protection of the 500 kV Power Grid in Northeast China"]

[Text] The power system in Northeast China has formed a 500 kV looped network centered around Yuanbaoshan, Jinzhou, Liaoyang and Haicheng. There are five lines, eight transformers, and four electric reactors in operation. This is an introduction of the operation of the system and its relay protection.

I. Layout of Relay Protection

All five 500 kV lines are protected by Chinese-made PXH-27 and PXH-19(16A) rectifier relays and JGBJ-501, JL-500 and JZC-501 transistor relays. The redundancy is based on the principle of similar theory but different structure. It is equipped with two sets of high frequency exclusive grounding and phase distance protection. In addition, a three-segment reserve distance serves as a backup protection against shorting between phases. A dual four-segment zero sequence direction surge protection system serves as backup ground fault protection. Fast phase current breaker and zero sequence fast current breaker serve as ancillary protection. Furthermore, it is equipped with dual general closers.

With the exception of the main transformer for power plant No 2 at Yuanbaoshan, all transformers and electric reactors used for protection are made domestically. The main protection includes gas and redundant differential protection. There are two kinds of layouts. The four main transformers in the Dongjiadian and Liaoyang substations employ a total differential transistor relay as the main protection. In addition, the 220 kV and 500 kV side are equipped with a differential rectifier relay as independent protection. The Wangshi and Dongfeng substations have two identical total differential systems as the two main protection units. One of them is a transistor type and the other is a rectifier type. The transistor relay is the JCD-41 balanced relay which is based on the intermittent angle locking principle. The rectifier relay is the LCD-8 generator differential relay. The total differential rectifier relay protection employs the LCD-4 differential relay which is based on a second order harmonic braking principle.

The connecting transformer at the Yuanbaoshan power plant uses BCD-22 and BCD-33A transistor-based balanced relays to form a total differential protection system (on 220 and 500 kV side) and a partial differential protection system (for 220 kV, 500 kV and neutral) as the two main protection systems.

In addition to the Yuanbaoshan power plant, the main backup protection for transformers uses an impedance protection system (with offset), as well as zero-sequence protection to cut off grounding of the 220 and 500 kV lines. All transformers are equipped with over excitation protection.

At Yuanbaoshan, zero-sequence directional surge protection transistors are placed on the 220 and 500 kV side and of the connecting transformers and composite voltage lockout surge protectors are used on the 500 kV side as backup protection against grounding and short between phases.

The protection layout for the No 2 generator/transformer unit was done by GEM Corporation of France. Main protection includes a major differential relay for the generator/transformer unit, a generator differential relay and a transformer differential relay, as well as backup protection such as a zero-sequence surge protector on the 500 kV side, a transformer over excitation protector and other protection for the generator.

The four 500 kV reactors are protected by the JDK series transistors, including longitudinal drop, fast current cutoff between phases, zero-sequence, inter-loop and gas protection or electromagnetic protection.

As for bus-bar protection at the five substations, PMH-1 dual fast bus differential protectors that operate based on the principle developed by ASEA Corporation are used.

II. Operation of the System—Its Protection and Automation

1. Initial Operation of the System

In its initial operation, problems associated with the 500 kV system were essentially being fixed as they occurred. All line problems were caused by arc light resistance grounding, which is as high as 300Ω. There were 10 incidents of equipment failure due to heavy fog, i.e., 58.8 percent of total failure. Two neighboring lines malfunctioned and were down for a total of six times. They were all caused by the overflash of porcelain insulators in fog at different sites. There were four manual forced transmission line failures during heavy fog. Heavy fog caused the porcelain jackets of parallel breakers to flash over. Thus, the parallel standby generator and the system single phase are not synchronized, leading to system oscillation. The 500 kV transformer broke down because there was a short between loops in the single phase coil.

2. Operation of Relay Protection and Automatic Set-Up

From 1984 to the end of February 1989, relay protection has been tripped 120 times. Out of 110 times due to system failure, 107 times were tripped correctly. The accurate tripping rate is 98.17 percent. Line protection has been tripped 106 times. High frequency protection was tripped correctly 34 times. Zero-sequence protection was tripped accurately 34 times and once incorrectly. Distance protection was tripped correctly four times and incorrectly once. Reclose was tripped nine times and successfully twice. Non-whole phase protection was correctly tripped five times. Phase current fast cutoff was tripped correctly five times and over-voltage protection was correctly tripped once. Based on the type of protection, transistor protection tripped 56 times with 100 percent accuracy and rectifier protection tripped 50 times out of which 48 times were correct, resulting in a 96 percent accuracy rate.

Protection was incorrectly tripped 13 times. Poor product quality was the cause for six such incidents, which accounted for 46 percent. Defective installation was the cause of two such events, which accounts for 15 percent. Basic construction and operation personnel error caused two such incidents, which is 15 percent. Relay personnel error caused it to happen two times, which is 15 percent. One incident was caused by unknown factors, which is 7.7 percent.

Another special feature is that protection was only improperly tripped three times when the system failed. During routine operation, there were 10 improper tripping incidents, which accounted for 76.9 percent.

3. Problems and Countermeasures Associated With Relay Protection and Automatic Safety Equipment

(1) During the initial stage of operation of a long line or in the middle of thunderstorms, the high frequency protection receiver/transmitter is frequently activated by interference signals, up to over 50 times an hour. In some cases, the receiver/transmitter is kept on constantly. This may cause the following harmful effects: distracting the focus of attention of operators making it easy to make mistakes, damaging the receiver/transmitter, and causing the malfunction or delay of high frequency protection.

Based on tests, the characteristics of high frequency channel interference signals include large frequency variation and wide bandwidth with a normal voltage of 1-2 volts. However, transient impact signal amplitude may be very large, as high as 2-60 V_{p-p}. But, it lasts less than 1 ms most of the time. When an elevated ground wire is grounded through the discharge gap, if improperly installed, a high frequency interference signal would be generated as the discharge gap breaks down with the peak at approximately every 3.3 ms. Its bandwidth is also very wide, with an amplitude as high as 200 V_{p-p}.

The following two measures were taken. The sensitivity of the receiver was lowered by setting the threshold voltage of reception to 1.5 N. In addition, both sides of the line must have analog positive direction exit failure. Reliable closure can be ensured under the condition that the residual in the channel is only 0.3 N. The remote tripping time delay of the rectifier receiver/transmitter was increased to under 4 ms.

(2) When the voltage rises in the 500 kV system due to insufficient reactive compensation, the second order zero sequence voltage of the capacitive voltage transformer (CVT) is often too high. The transistor protector sends out a "device failure" signal and takes it off-line. To this end, any zero sequence voltage relay must satisfy the following two conditions. It must have a third order harmonic filter and should be set to avoid the maximum voltage, $3U_o$, that may be present under normal conditions. In addition, its sensitivity under various failure conditions must be ensured. Based on analysis and verification, this zero sequence is not caused by CVT saturation. Rather, it is generated because the main 500 kV transformer is saturated from a voltage rise caused by insufficient reactive compensation. Therefore, to the extent possible, zero sequence current components, instead of zero sequence voltage components, should be used in relay protection of the 500 kV system.

(3) The phase selection element used to measure abrupt changes of phase current difference was set too high. As a result, phase selection could not be done properly when a single phase was grounded through a large arc. After further calculation, the phase selection element was reset to 0.1 A. Nevertheless, the phase selection element of the rectifier protection could not be set lower. That type of element might still not trip under the above condition.

(4) Cathode ray oscilloscope cannot meet the needs of a 500 kV grid. A high performance intelligent wave recording device should be used.

(5) All 500 kV lines are plugged into a single phase closer. The success rate of the closer is only 22.2 percent. The main reasons are that the line is grounded through a large

arc resistance and the first order current change is small. The phase selection element is set too high to trip the triple phase. There are many transition failures which tripped the triple phase. Shortly after manual transmission of fog overflashed lines was done, single phase grounding failure took place. Because the closer was not fully charged, it could not close after the single phase breaker was tripped. As a result, the lines were operated over a long period of time without whole phase charging. In order to ensure the operation of these two sets of reclosers, we eliminated the original design which involved mutual discharge and simultaneous input of both reclosers. Normally, only the switch-on connector of one recloser is used. The other recloser is plugged into the system in a similar manner. However, its switch-on connector is not tied into the system. The reclosing time may be set separately according to the operating mode. A split-phase switch-on connector must be installed in the output of the switch-on circuit of each recloser to avoid the situation that it cannot reclose due to a parasitic circuit.

(6) A defective timing triode in the transistor protection system of the main transformer caused protection failure. The following measures were taken. The self-maintained output relay circuit in the original design was eliminated. The interference resistance of the dc circuit was improved. In order to protect the current lockout element, negative sequence increment lockout element and zero sequence voltage lockout element, a time delay was added to the last stage output triode to avoid fluttering during a switch over of the power supply. When the "equipment abnormality" signal appears, the corresponding abnormality protection connector is disconnected to prevent the switch-on of a contravariant power supply.

(7) A reliable voltage break lockout device must be included in the low impedance protection of the main transformer. A low impedance rectifier without such a break lockout device should not be used routinely. It may serve as a backup.

(8) Differential protection for the main transformer and the reactor no longer used the closed-loop lockout scheme. Instead, a current inductance differential circuit is used to prevent failures due to secondary cutoff of the inductor and damage to the differential relay.

(9) In view of the fact that over excitation protection might trip by mistake in the primary system and in secondary CVT transient process, it only provides a signal and does not initiate differential protection. Differential protection should not be incorrectly tripped during over excitation.

III. Deficiency of the Protection Principle of the 500 kV Line and Quality of Work

1. When the grid oscillates first and a line is shorted, or when two lines are shorted, the high frequency lockout distance protection of the latter line cannot trip instantaneously.

2. The performance of the receiver/transmitter is poor. The output impedance cannot be maintained constant. The receiving filter does not work effectively. It cannot operate with a carrier in parallel. Furthermore, it requires a large frequency gap which makes it difficult to provide an operating frequency band to the receiver/transmitter. Originally, the receiver/transmitter was equipped with an experimental voice communication system. However, the present unit does not have a voice communication device. The operating units were forced to purchase such devices or have dedicated telephone lines, which is a major inconvenience.

3. The 500 kV self-coupling transformer has 500 and 220 kV zero sequence grid in series. The two main 500 kV transformers operate in parallel. Because insulation has not been certified, it is required that the neutral be grounded. It cannot be grounded through a gap. Therefore, it is impossible to maintain relative constancy of zero sequence impedance. Hence, zero sequence protection can no longer meet sensitivity and selectivity requirements. Thus, grounding distance protection is required as a backup. To protect the system from grounding through a large arc light resistance, a segment of inverse time-limit zero sequence protection must be used to supplement grounding distance protection.

4. Existing protection cannot satisfy a semi-switch line connection.

5. Forty-six percent of incorrect tripping is attributed to component quality. The manufacturers should take a hard look at this problem.

IV. Conclusions

On the basis of perfecting and improving the existing 500 kV protection system, the power grid in the northeast employed the Chinese-made integrated circuit protection and microcomputer protection. In addition, foreign-made protection has been imported in the project between Haicheng and Dalian. After analysis and comparison, in conjunction with the experience learned from the imported system and the prospect of development in the relay protection industry in China, it has been decided that domestically made protection will still be the primary system for the 500 kV power grid in the northeast. However, transistor and rectifier based protection will no longer be used. Instead, IC and microcomputer protection will be used to protect various pieces of equipment in the 500 kV system in order to meet the ever more rigorous requirements of the power grid.

North China

906B0028B Beijing DIANLI JISHU [ELECTRIC POWER] in Chinese 5 Dec 89 pp 11-13

[Article by Wen Jianzhong [3306 1696 1813] of the Control Office of North China Power Bureau: "Layout and Operation of Relay Protection of the 500 kV Power Grid in North China"]

[Text] The 500 kV power grid in North China has been in operation for over 3 years. A large number of incidents showed that relay protection is essentially functioning properly to meet the needs of the 500 kV system. However, some problems also surfaced. This is a summary of the layout and operation of the protection system.

I. Layout of Relay Protection and Automatic Safety Equipment

The 500 kV power grid in North China is completely protected by imported equipment, primarily manufactured by Siemens in West Germany and GE.

(1) Line Protection

The line is equipped with two sets of primary protection units. One is a GE SLVP-SLCN directional high frequency system which is based on a comparison of positive sequence distance to negative sequence direction. It operates in the over-range enabling mode. In order to cut off breaker output failure rapidly, the system is equipped with a variety of direct trip elements that reflect different types of failure (without going through high frequency signal lockout). The system itself is equipped with a phase selection element. It takes approximately 30 ms to activate with high frequency tripping and 10 ms with direct tripping.

The second unit is a Siemens 7SL32 high frequency distance protection system. Through a high frequency interface, it may operate in over-range enabling and under-range enabling mode (usually trips independently without high frequency signal lockout). The sensing element and activating element are based on directional and offset tetragon principle, respectively. The protection comes in sections with backup capability. It includes a four-section phase distance and a four-section grounding distance unit. The grounding distance tripping element also acts as a phase selection element. Whole phase oscillation lockout is used based on the large tetragon principle. There is no lockout for non-whole phase oscillation. The unit is also equipped with a fast-break direct-trip element for phase current (for a semi-switch line and for short lead protection). The initiation time of the unit is approximately 30 ms and that of the direct-trip element is about 10 ms.

These two primary protection systems provide redundancy based on different principles.

The line is also equipped with an independent and comprehensive backup protection system (Siemens Model 7SL32, similar to the primary protection system without the high frequency portion). In order to avoid inability to trip due to failure from high resistance grounding of the breaker outlet, a zero-sequence directional surge protector (Siemens Model 7SH20) was added. The effectiveness of this backup protection has been significant.

In addition, based on the nature of a long line high voltage system, over-voltage protectors (Siemens Model 7TU10) have been installed to serve as primary over-voltage protection for the lines and bus. Besides tripping the breaker on its own side, the breaker on the other side is also tripped through the Siemens high frequency protection channel.

At Beijiao and Fangshan (1 ½ switch line), automatic reclosers were installed based on the breaker layout (Siemens Model 7Vk31). Two reclosers were installed in the Datong-Shentou line for redundancy. Normally, the Siemens recloser is in use and the GE recloser is on standby.

(2) Bus and Breaker Malfunction Protection

In principle, redundant protection is provided to 1 ½ switch lines. Every bus at the Beijiao and Fangshan substation has two sets of single bus differential protection systems (Siemens Model 7SS10). At the Datong and Shentou power plants, two sets of bus lines are equipped with a unit of differential protection, including bus selection element and activation element. The bus difference is derived from the absolute value of the sum of all branch currents and the sum of all absolute branch currents. The differential element compares the phase and ratio of the first half wave. It takes approximately 10 ms to initiate the system.

Breaker failure protection (Siemens Model 7SW21) is installed based on the 500 kV breaker layout. Tripping and phase current are used as the criteria to determine malfunction. After a short delay, the failed breaker is tripped again. After a long delay, all other breakers connected to the same bus are tripped. At the same time, the breakers on the other side are also tripped through the high frequency channel.

(3) Automatic Safety Equipment

The failure wave recorder (Siemens Model R8) has sufficient memory to store for 170 ms prior to failure to reflect the transient process of failure and to continuously monitor the operation of the system. There are 14 analog electrical parameters and 16 protection points. The record is kept with an ultraviolet sensitive paper which includes the date and time of incident. One recorder has been installed in every two circuits. Apparently, this does not meet system operation requirements.

The Siemens protection tripping malfunction detector (Model 7SE12) is used. Electrical components for tripping are converted to digital signals through an A/D converter. The required impedance, number of kilometers, poles, and line length are calculated and displayed by software. The accuracy is approximately 3 percent. A detector is placed on either side of every line.

(4) Bus Connection (or Bypass) Protection

The Shentou power plant bypass and the two bus breakers at the Datong power plant are protected according to the layout, but there is no carrier. When a

bypass breaker is used instead of a line breaker, it is necessary to switch the line channel and carrier.

(5) High Frequency Channel Equipment

A dedicated carrier, multi-purpose channel coupling scheme is used. The same channel is used by the two primary protection units, as well as for communication. It is also equipped with a Siemens Model ESB-400 single side-band carrier and a Model SWTF-6 acoustic interface. The GE unit includes a GE Model D single side-band carrier and a Model NN45AX acoustic interface. A frequency shifting scheme (FKS) is adopted for channel transmission.

Static relays manufactured by the Nanjing Electric Power Automatic Equipment Plant are used to protect the 500 kV transformers and reactors.

(1) Transformer Protection

Based on the principle of focusing on primary protection, three sets of differential protection systems are in place. Two are serial differential units and the other is a medium to high voltage phase-split zero-sequence differential system. The relays used are Model JCD-63, which is based on the second harmonic principle, and JCD-41, which is based on the interrupted angle lockout principle. Hence, there is redundancy in primary protection based on different principles.

Backup protection follows the principle of reasonable simplicity. It is in a near backup mode. In order to protect against ground fault, a two-section zero-sequence surge protector is put in place to avoid excited surge current. A one-section inter-phase impedance protector acts as a backup for failure between phases. In addition, other common protection schemes such as overload protection, non-whole phase protection, and gas protection, are also employed. In order to prevent voltage surge in large transformers which may overheat the equipment due to excessive excitation, over excitation protection is also provided. In the 1 ½ switch mode, when the transformer shut down and the breakers operate in series, it is switched to a short lead for protection.

(2) Reactor Protection

There are two sets of main protection for the reactor. One is split phase differential protection based on the interrupt angle lockout principle. The other protects between loops. High sensitivity zero sequence power relay is used as the primary protection against single phase grounding and inter-loop shorting. Routine protection is used as the backup. After it is activated, breakers on both sides are also tripped.

II. Brief Description of Incidents Associated With the 500 kV System

Statistically, the 500 kV system in North China has a high failure rate. In 1986 and 1987, it had the highest incident rate in China. There were two bus failures in China and both took place in North China. This has something to do with the geographic location (hills and mountains) and harsh weather conditions in the region. However, it is also closely related to the quality of construction and equipment, insulation standard, and maintenance. Up to the end of 1988, there have been 15 line failure and 2 bus failure incidents. According to failure type, there were 15 single phase grounding incidents, one single phase broken wire grounding incident, and one shorted two-phase grounding incident. Based on the phase of failure, phase C grounding occurred nine times, phase A grounding five times (including once due to broken wire), phase B grounding two times, and shorting and grounding of phase B and C once. Based on the cause, wind was the cause five times, overflash of porcelain bottle by lightning five times, external forces (including birds) five times, overflash due to heavy fog one time, and accidental arc shorting one time. Other than one permanent failure caused by fallen wires resulting from metal fracture, the others were temporary incidents. Because of fast tripping time, the wire damage was minor. This made it difficult to pinpoint the location of problem.

III. Operation of the 500 kV Protection System

Based on the above analysis, relay protection essentially operated correctly to shut off rapidly the system during failure which greatly reduced the extent of burn damage to the equipment and avoided any further failure. Out of the 14 transient line failures, with the exception of one case in which the phase B and C recloser would not reclose and another case in which the main protection failed and the recloser would not close after the backup delayed relay was tripped, the recloser successfully reclosed after the protection system was tripped in the remaining 12 cases to restore the power grid to normal operation. Hence, the single phase recloser is very effective in ensuring the safety and stable operation of the system.

From the record of the protection system for over 3 years, the accuracy rate of the 500 kV system has been higher than the national average every year. Moreover, it is getting higher each year, reaching 95.1 percent in 1988. The number of incidents dropped drastically, from eight in 1986, six in 1987, to two in 1988. The accuracy rate of the 500 kV system in the Beijing-Tianjin-Tangshan power grid has been over 90 percent for 3 years. It reached 100 percent in 1988.

The imported protection system for the 500 kV grid performs better than the overall protection system. The Siemens high frequency distance unit was tripped 32 times, the backup distance unit 30 times, and the bus protection unit 2 times. The accuracy rates are all 100 percent. The Siemens recloser was tripped 37 times. Due to an insert problem, it did not close in one incident. In the remaining 36 times, it successfully reclosed. The accuracy rate is 97.3 percent. The GE high frequency direction unit was tripped 33 times. It failed to trip in three cases. The accuracy rate is 90.9 percent. (These three incidents occurred in 1987 and the causes are still

unknown.) The accuracy rates for the Siemens remote tripping unit and breaker failure protection device are lower. The remote tripping unit was activated four times. It was incorrectly tripped once due to faulty welding of elements and the accuracy rate is 75 percent. The breaker failure alarm was tripped twice; once positive and once negative. The accuracy rate is 50 percent. The mistake was made by an error in the Chinese-designed secondary circuit. The Siemens fault was recorder and failure ranging unit are 88.6 and 96.7 percent perfect, respectively. Therefore, the failure ranging device is very effective in locating the point of the problem.

The protection system acts very promptly. Based on the recorder, it cuts off the failure in 30-40 ms on the side close to the fault. On the side far away from the fault, it usually takes 60-70 ms to receive the enabling signal to trip. The breaker takes approximately 20 ms to trip and the channel transmission time was measured to be about 10 ms. The time used to initiate the pure protection mechanism is 10-40 ms. The direct trip element acts within 12 ms. The bus differential protection unit takes approximately 30 ms to activate. It meets the requirement specified in the "Power Grid Stability Guideline" to break within 100 ms after failure in order to ensure the safety and stable operation of the system.

Despite the high accuracy rate of the imported 500 kV protection system in North China, there were instances in which it failed to trip or tripped incorrectly. The GE high frequency direction protection unit failed to trip three times in 1987. The causes have not been found despite repeated investigation after the incidents. This may threaten the safety and stable operation of the system in the future. To this end, a dynamic simulation experiment will be done to reassess the behavior of the GE protection unit. The Siemens remote tripping unit activated once without any fault in the line. It was determined that improper welding of certain elements at the acoustic interface of the Siemens dedicated carrier in the Datong power plant was the cause. A remote tripping signal was sent by mistake which tripped the breaker in the Shentou power plant.

IV. Conclusions

Based on the record for the past 3 years, the imported protection system is a success. It has ensured the safety and stable operation of the system. However, the following problems need serious attention:

1. In the process of importing equipment, the department in charge should physically participate and issue specific assignments. The operating department must send people to be involved in the entire process in order to make sure the necessary prints and data are obtained.

2. Do not import too many kinds of plant equipment; it is difficult to control and manage.

3. Spare parts and components should also be imported in sufficient quantity.

4. There is a serious shortage of trained professionals and the quality of personnel is low. The operational management work apparently cannot meet system requirements. This does not meet the needs of the development of electric power and must be resolved promptly.

Central China

906B0028C Beijing DIANLI JISHU [ELECTRIC POWER] in Chinese 5 Dec 89 pp 14-17

[Article by Li Fadi [2621 4099 2769] of the Control Office of Central China Power Bureau: "Layout and Operation of Relay Protection of the 500 kV Power Grid in Central China"]

[Text] **I. Protection Layout**

Since the Pingwu (Yaomeng-Shuanghe, Shuanghe-Fenghuangshan) 500 kV line was put on-line in 1982, a 500 kV skeleton grid centered around the Gezhouba hydropower station has been formed in Central China. There are 10 500 kV ac lines, 1,700 km in total length. There are eight substations. The relay protection layout is shown in Figure 1.

With the exception that the high frequency directional protection unit manufactured by Nanjing Automation Equipment Company has a dedicated transmitter/receiver connected to phase C, other units share a multi-user BBC carrier connected to phases A and B. Fiber-optical channels are only used in current converter stations I and II at Gezhouba.

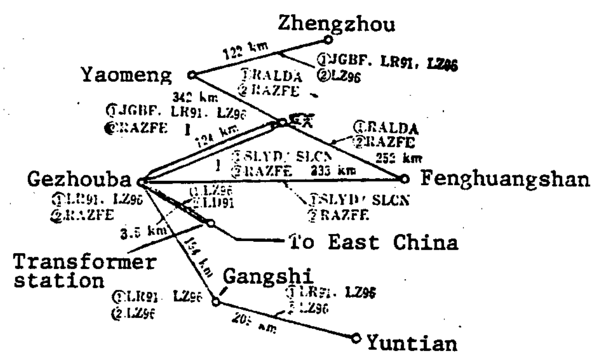

Figure 1. Protection Layout of 500 kV Lines in Central China

LR91, LZ96 and LD91 are the traveling wave, distance and short line longitudinal difference protection units manufactured by BBC Corporation, respectively. JGBF is the high frequency directional protection unit manufactured by Nanjing Automation Equipment Company. RALDA and RAZFE are the traveling wave and distance protection units manufactured by ASEA Corporation of Sweden. SLYP/SLCN are the high frequency directional units manufactured by GE.

II. Protection Action

The accuracy rate of protection action has not been high, basically within 50-70 percent. The situation is as follows.

Since the 500 kV grid was officially put in operation, there have been 10 failures, including single phase bus grounding one time, transformer failure three times (transformer itself one time and lead wire failure two times), and line breakdown six times (single phase grounding five times and shorting between phases one time). The protection system was able to quickly disengage faulty portion of the power grid within 60-70 ms. This shows that the reaction time for both domestic and imported systems can meet the operating requirements. In addition, it also proves that the scheme to have a redundant protection system based on two different principles is correct.

The six line failure incidents were successfully dealt with by the main protection unit of the 500 kV line. It was tripped a total of 40 times, and 37 times correctly. The recloser failed to trip once. The American-made high frequency protection failed once. The RAZFE distance protection unit failed once. The accuracy rate is 92.5 percent.

Protective Action of the 500 kV Power Grid in Central China

Year	1982	1983	1984	1985	1986	1987	1988
Item/number							
Total	16	14	8	2	12	18	34
Incorrect	7	6	3	2	5	6	11
Accuracy (%)	56.3	57.1	62.5	0	58.3	66.7	67.6

III. Analysis and Improvement of the Main Protection and Channel Action

1. RALDA Traveling Wave Protection

The RALDA traveling wave protection unit made phase selection errors in dynamic simulation tests. After the manufacturer provided a new phase selection element, it performed accurately in later dynamic simulation tests as well as in actual incidents.

(1) Misoperation Outside Area

This protection unit misoperated three times outside the area when it was first put in operation. The wave form of the traveling wave directional detector was recorded by a storage oscilloscope and is shown in Figure 2.

Due to alternate appearance of reverse and forward traveling wave output wave form, also because of the transient effect of the filter in the traveling wave voltage and current protection circuit, the first reverse output

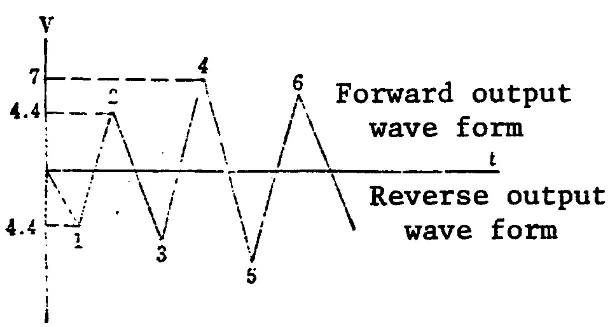

Figure 2. Traveling Wave Directional Detector Wave Form

wave is under the 4.4 V threshold. Reverse element would not react to it. The second forward output wave is often larger in amplitude than that of the first wave and may exceed 4.4 V. Forward element locks out the action of reverse element and keeps it out of action. Although the third reverse output wave form has sufficient amplitude, it has no effect because forward lockout has already taken place. If the fourth forward wave form exceeds 7 V, the forward tripping element would act to cause a misoperation of traveling wave protection.

It seems to be a mistake to choose the same threshold, 4.4 V, for a traveling wave protection unit that the forward and reverse output mutually lock out each other. It should use the forward output to lock out the reverse output and have the same threshold as forward tripping, i.e., 7 V. Thus, the reverse to forward sensitivity ratio is 1.6.

(2) Improvement of Traveling Wave Protection

When the line is switched on, if there is a fault, due to the presence of a voltage inductor in the protection circuit, the sudden voltage change is zero and the traveling wave protection unit would not react to it. It is necessary to add an extra protection which trips when the current change exceeds a specific value. On 9 November 1982, single phase permanent failure occurred between Guodingshan and Guanshan. The traveling wave protection on the Fenghuangshan side of the Shuangshan-Fenghuangshan line misoperated and tripped the system.

As shown in Figure 3, the phase difference protection unit in breaker 23 at Jingmen tripped incorrectly after single phase grounding in the Guodingshan-Guanshan line. The phase difference protection in the Guodingshan to Guanshan line did not trip. Section I of the zero sequence protection of breaker 11 at Guodingshan

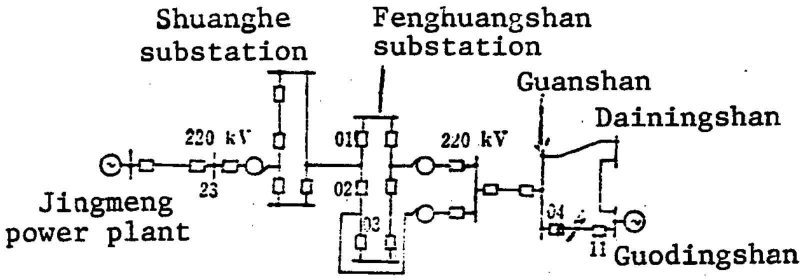

Figure 3. System Diagram During Permanent Single Phase Grounding in the Guodingshan-Guanshan Line

reacted to trip phase B. It took 1 s for Section II of zero sequence protection of breaker 04 to trip. Therefore, when breaker 11 at Guodingshan reclosed at 0.8 s, the traveling wave protection unit reacted to trip breakers 01 and 02 at Fenghuangshan because all four conditions were met under this special operating mode.

This additional traveling wave protection should not be in operation over a long period of time. It has been changed so that it kicks in after the breaker is switched on and kicks out with a 250 ms time delay.

(3) Sensitivity to Some Transient Processes of the Grid

Traveling wave protection is overly sensitive to certain transient processes in the power grid. For example, there was a phase C failure between Yaomeng and Shuanghe in April 1987. Traveling protection on both sides reacted to it and distance protection did not respond at all. From the wave form pattern recorded at Shuanghe substation, there was no change in the current and voltage at the operating frequency. Inactivity of distance protection was basically correct. At that time, there was a thunderstorm at Yaomeng. A few high frequency spikes were added to the voltage and current wave form. The amplitude of sudden current change was approximately 200 A (current was at 400 A prior to incident) and the frequency was 5-7 Hz. The traveling wave protection unit on the Shuanghe side of the Yaomeng-Shuanghe line was set at 2400 A in independent mode and 520 A in dependent mode. Based on the frequency spectrum of the traveling wave protection filter manufactured by Nanjing Automation Equipment Company, the frequency is below 5-7 Hz and the action value is approximately 1/10 to 1/13 of the amplitude at operating frequency. Hence, the independent traveling wave protection unit on the Shuanghe side might respond. As a matter of fact, it was tripped. More work needs to be done to improve the misoperation of the protection system when the line is subject to transient discharge during thunderstorms.

2. RAZFE Distance Protection

The RAZFE distance protection unit operates normally in the grid. It has been activated 11 times with 10 correct responses. It provides an important protection to the safety of the power grid. The following problems have been uncovered in operation.

(1) In dynamic simulation, misoperation of reverse triple-phase shorting was found at some shorting switch-on angles. Forward triple-phase did not respond. During testing, Hubei Power Testing Institute found that an active filter was not designed in the analog current I_{ZR} circuit in the D_{1MR} direction line that reflects a forward three-phase short. At some shorting switch-on angles, the high frequency component in the shorting current is so large that the square wave is chopped to cause misoperation or inaction. An active filter has been installed in this circuit.

(2) During dynamic simulation, it was found that the threshold current for I_{BC1R}, I_{BC1S} and I_{BC1T} was 0.15 I_n, which is not consistent with the description in the manual (i.e., 0.2 I_n). This might also cause the failure in the event of a forward triple-phase short in some operating modes.

(3) On 15 March 1987, phase B of the Gezhouba-Fenghuangshan line suffered a temporary failure. High frequency directional protection and distance protection successfully tripped and reclosed the single phase. High frequency directional protection and distance protection on the Fenghuangshan side began to trip phase B. However, 588 ms later, "2φ" distance protection tripped the breaker. After the incident, it was found that distance protection was set at the correct value. This incident was not recorded by the wave recorder on either side. Nevertheless, we suspect that after the faulty phase tripped relays on both sides the free oscillating voltage generated by the reactors and capacitance in the circuits on both sides caused the phase sequence of the compensating voltage of the three phases to become negative. Thus, the multi-phase compensating reactance relay was tripped by mistake. This is because a 40 Hz oscillating voltage was discovered in the faulty phase of the Yaomeng-Shuangshan line in the wave form recorder and the Gezhouba-Fenghuangshan line similar circuit parameters. Qinghua University is conducting a simulation study on this problem.

3. SLYP/SLCN Direction High Frequency Protection

This protection unit was tested at the dynamic simulation laboratory in Central China Institute of Technology before it was put in operation. It was found that it worked correctly under the following failure conditions. $(M_1)_1$ positive sequence reactance relay was set at 90 percent line reactance. However, the first batch of high frequency protection units did not work very well. The accuracy rate was only 50 percent. Our experience revealed the following concerns:

(1) The contacts of various inserts were not good, which might cause erroneous switching of the logic circuit. It was necessary to carefully adjust the angle of every insert to ensure a reliable contact.

(2) The phase selection element in the protection unit must be carefully calculated. The triple-phase selection depends upon V_1, V_{1x} and M_{1T}. To activate M_{1T}, we have to go through $(I_o\text{-}KI_1)_{(T)}$ lockout. Therefore, it is necessary to verify that $(I_o\text{-}KI_1)_{(T)}$ can reliably lock out M_{1T} during single phase grounding at the output. However, when two phases are grounded $(I_o\text{-}KI_1)_{(T)}$ should not respond. This is more difficult for the Gezhouba hydropower plant side because all the 500 kV transformers there are either directly grounded or grounded through low reactance. When all generators are running, $X_{o\Sigma}$ is very low. It is unavoidable that zero sequence current would increase when two phases are grounded. It may result in $I_o = 0.7\ I_1$ and $(I_o\text{-}KI_1)_{(T)}$ can no longer meet the requirement. Today, K is increased by an appropriate amount before we calculate whether $(I_o\text{-}KI_1)_{(T)}$ can remain still when two phases are grounded at a distance from the output. In addition, we also consider whether it is compatible with the phase selection element V_1.

(3) The protection unit incorrectly sent a reverse direction failure signal. On 14 August 1988, the lead wire of No 10 step-up transformer at Gezhouba failed. It was incorrect for the high frequency protection unit on the Gezhouba side to send an outside-the-area reverse direction failure signal. A review of the incident recorder at Fenghuangshan substation showed that the signal was received 100 ms after the incident. By that time, the fault was dealt with. Since a multi-purpose carrier transmitter/receiver is used, there is a 40 ms return delay. The reverse direction element returned before signal reception. This caused the high frequency direction protection unit at Gezhouba to issue a wrong signal. This problem can be resolved by lengthening the return time of reverse direction element.

4. LZ-96 Distance Protection

During an artificial grounding experiment along the Gezhouba-Gangshi-Yuntian line, the triple-phase breaker was tripped by mistake during single phase failure. This is attributed to the fact that BBC Corporation allowed the LZ-96 distance protection unit and the line overvoltage protection unit to share the same tripping outlet logic circuit. As single phase failure began, distance protection sent out signals for tripping and T phase selection correctly. However, after the T phase switch was tripped, the wave form recorder showed that a rise in transient voltage of normal phases which triggered the overvoltage protection mechanism and activated phase selection R, S, and T. When combined with the tripping signal D sent out by distance protection, phases R and S were also tripped. The transient overvoltage protection circuit was modified to add a time delay before activating phase selection R, S, and T.

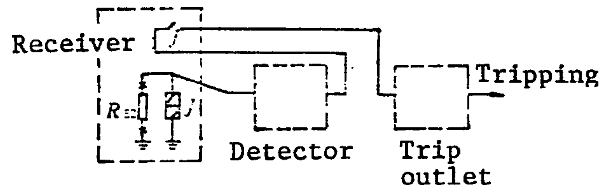

Figure 4. Multi-Purpose Carrier Outlet Tripping Circuit

5. Multi-Purpose Carrier Channel

(1) The multi-purpose carrier in the Shuanghe-Fenghuangshan line misoperated four times. Once, the carrier channel received a wrong signal after an isolation switch was pulled at Fenghuangshan substation due to a defective element in the carrier channel. The other three incidents happened because transistors in the detector of the multi-purpose channel malfunctioned due to excessive heat in the summer since the detector is located on top of the power supply. Since then, improvements have been made. Resistor R_{52} in the reception chamber was removed and a new 24 V micro-relay J has been installed in series with the outlet tripping circuit of the carrier as shown in Figure 4.

(2) The NSD-61 multi-purpose carrier manufactured by BBC Corporation had four incidents of mis-reception.

These incidents have the following in common. One side of the carrier channel did not transmit any signal and register a count while the other side received a signal and registered a count. The insulation between the 380 ac end and the +881 dc end in the outdoor terminal box of No 21 breaker at Shuanghe substation broke down and sparks were seen. After on-site inspection and simulation, it was found to be due to the fast response time of the transmitting relay (less than 1 ms). When high frequency interference voltage pulses appear in the dc power source, the transmitter relay flutters due to distributed capacitance of the secondary cable. In addition, due to the delayed return in the electronic circuit of the transmitter, intermittent pulses were expanded into a continuous wave to cause the carrier to transmit a complete set of codes. Thus, the receiver on the other side received this signal and registered a count. Because of high mechanical inertia, the counter on this side did

not register a count. Based on this finding, we implemented the following measures to improve the NSD-61 multi-purpose channel:

1) Eliminate sources of interference. The Gezhouba substation changed the dc fuse to a tube-shaped fuse. The Shuanghe substation completely isolated its ac and dc terminals placed in outdoor terminal boxes.

2) In order to eliminate the effect of high frequency interference voltage pulses during a dc breakdown, a reverse diode was installed in series with the transmitter relay coil. Furthermore, a parallel resistor was added to the transmitting input circuit to speed up capacitor discharge in order to reduce the return time of the circuit from 3 ms to 0.5 ms.

3) Reception code of the NSD-61 multi-purpose carrier was increased to lengthen the transmission time. It has been raised from 12 ms to 30 ms.

East China

906B0028D Beijing DIANLI JISHU [ELECTRIC POWER] in Chinese 5 Dec 89 pp 17-20

[Article by Wu Xiaomei [0702 2556 2734] of the Control Office of the East China Power Bureau: "Operation and Management of Dual High Frequency Protection for Power Grid in East China"]

[Text] **I. Introduction**

Since the first 220 kV line was put into operation in July 1958, there are 196 220 kV lines and nine 500 kV lines in East China. Load centers are far from large power sources. The grid handles a large volume. System stability becomes an important issue. Therefore, relay protection requires fast, selective elimination of breakdowns. In addition, because there are numerous short lines in the cities, the systems consist of a network of long and short lines. It is very difficult to have every level meet certain rigorous relay protection requirements. To this end, the East China power grid depends primarily upon high frequency protection to raise its transmission capacity, to ensure the stability of the system, to simplify the overall coordination of relay protection, and to satisfy the safety requirements.

In order to ensure that at least one high frequency protection system operates without interruption, the connecting lines in the power grid are all designed with dual high frequency protection devices. One is phase differential high frequency protection and the other is high frequency lockout zero sequence protection. The transmitter/receiver can be switched to work in concert with the distance and zero sequence protection mechanisms of other bypass breakers to form a high frequency lockout protection system. This type of layout costs less, operates flexibly and effectively. By the end of 1988, 160 lines were equipped with redundant high frequency protection and 20 lines were covered by single high frequency protection. Terminal lines are not usually equipped with high frequency protection.

II. Superiority of Uninterrupted Operation of High Frequency Protection

Because of abnormality and routine maintenance which happen all the time in operation, in order to ensure uninterrupted high frequency protection of every connection line, it is necessary to have a redundant high frequency protection system. The advantages are as follow:

1. Cuts Off All Failures Rapidly To Ensure Grid Stability

High frequency protection is an important measure that improves the stability of the system. The presence or absence of high frequency protection has an impact of approximately 50 MW on a 220 kV connection line. In the past, because the system was not completely equipped with high frequency protection and it did not operate normally, several stability-related incidents happened in the absence of high frequency protection, leading to black-out covering large areas. On 31 July 1970 and 30 May 1971, the line between Lianbi and Changzhou failed. The fault was cut off at 0.6 s from section II. The grid lost stability and went into oscillation. In August 1973, after its high frequency protection was put into operation, the line malfunctioned again. Due to the fast tripping of high frequency protection, the grid remained in normal operation. Specifically addressing the long range, weak connection nature of the power grid in East China, and based on the lessons learned from previous incidents, the 220 kV dual high frequency protection system was gradually perfected. Over the years, no more stability-related incidents ever occur even in the middle of continuous transition failures involving large areas of natural disasters such as wind and heavy fog, or in the presence of faults that take place simultaneously. This fact demonstrates the superiority of the fast cut-off of failure by high frequency protection.

2. Simplifies Calculation To Coordinate Relay Protection at Different Levels

Because cities are densely located in East China, the 220 kV line corridor is very crowded. For instance, Shanghai has 6 power plants and 17 substations directly connected to the 220 kV grid. The shortest line is under 2 km. Hence, the coordination of long cross-province lines and short lines becomes a problem. Therefore, it is extremely difficult to coordinate the backup protection at various levels. In particular, it is very hard to rigorously set zero sequence current protection at different levels under varying operating condition. It is also difficult to cut off faults quick enough to ensure the stability of the grid. The installation of a dual high frequency protection system can simplify the coordination work and minimize the effect of the varying operating mode. For example, in the period section I that zero sequence protection is insensitive, it is protected by the high

frequency system in the neighboring line. Normally, the line would not operate without high frequency protection. In the section that zero sequence protection is sensitive, we can ensure sensitivity across the entire line, as well as coordination in terms of time with the neighboring line. The set value essentially remains constant regardless of the operating mode.

3. Phase Difference High Frequency Protection Is More Sensitive to High Resistance Grounding Failure

It happens quite frequently in spring that a high voltage line discharges through tree limbs and bamboo shoots in East China. It often occurs in stormy weather. As the tree or bamboo swings in the wind, high resistance grounding takes place. Because arc resistance is too high, circular distance protection is not tripped. Furthermore, because arc resistance varies, it is difficult to keep fixed interval zero sequence current protection operating continuously. Phase difference high frequency protection, however, has a higher flexibility with respect to negative sequence current. It responds correctly in the event of high resistance grounding. Since phase difference protection acts very rapidly, the extent of damage to equipment can be minimized.

III. Layout and Operating Specifications of the Dual High Frequency Protection System

A 220 kV line is usually equipped with two sets of high frequency protection units based on different principles in order to complement each other. One is a phase differential high frequency protection unit which employs a carrier channel to compare the current phase of both sides of the line. It uses the phase B channel exclusively and has four models, such as GCH-1, JGX-11A, JGX-11C and JGX-11D. From current inductor to channel, the phase differential high frequency protection system has its own dedicated system. It is a comprehensive and completely independent primary protection system. It trips from terminal N of the recloser. In order to expand the range of protection, it is also equipped with a three-phase trip breaker signal circuit. Over the years, it has a good operating record. Nevertheless, it also worked incorrectly several times. For example, the high frequency protection GCH-1 vacuum tube misbehaves because of a sticky contact, capacitor or transformer coil breakdown, low level of protection, and poor interference resistance. The JaX-11A transistor-based phase differential high frequency protection unit often responds inaccurately because of failure of power amplifier supply, frequency drift of ceramic filter, serious trailing, large lockout angle ambiguous region, reduction of phase comparison integral time, and damage to elements. The JGX-11C was improved based on JGX-11A. Several incorrect responses occurred due to soft breakthrough of triode 3DG80.

Specifically in response to these problems, we conducted a great deal of studies. Based on the "four in one" design requirement, new devices are being continuously developed to turn the situation around. To date, phase difference high frequency protection is still an ideal protection device for an ultra-high voltage line.

The other is a high frequency distance lockout, zero sequence protection which uses the "presence" or "absence" of high frequency signal to determine the fault zone and to lock out or open the distance and zero sequence protection of the line. It uses I_2/I_0 as the fault identifying element to activate signal transmission. Transmission time is under 10 ms. Section 3 in distance protection and sensitive section in zero sequence protection are used as to stop transmission. At 1.5 times activation level in the zero sequence current sensitive section and 0.7 times activation level of distance section 3, the time to halt transmission is required to be held at $t > 10$ ms + channel transmission time + Δt (Δ is the residual). If the transmission element on the opposite side failed to activate, the halt time on this side can still coordinate with the high frequency signal sent from the other side by remote initiation. Because the power grid in East China has developed gradually, there is a variety of models of protection devices. Therefore, the high frequency lockout protection system does not specify certain models in general. Different transmitter/receiver units can be used on either side. However, signal transmission time and halt time must be rigorously controlled to ensure coordination. As for the old protection system, the difference between transmission and halt time on the same side must be held within 30-40 ms. In addition, it is required that both sides can reliably lock out itself with a fixed residual time in response to a simulated high frequency signal from a remote site outside the region from the opposite side. Thus, the amount of coordination work between both sides can be minimized. In the process of maintaining and updating protection devices, coordination with the opposite side does not have to be considered. It is only necessary to rigorously control the difference between transmission and halt time independently.

In the event that the protection systems on both sides are tripped, to prevent the high frequency lockout unit on the side that is tripped later from failing, a breaker single phase tripping halt circuit is installed. The high frequency lockout protection unit is tripped at terminal M of the recloser. The high frequency channel and the communication channel share the same channel in phase A. A frequency divider filter is used to isolate the bands in order to increase the degree of protection and enhance interference resistance.

It does not cost much to install dual high frequency protection devices on a connection line. It is very effective in improving the stability of the power grid and in simplifying the relay protection system. It is worthwhile promoting.

IV. Operation and Management of High Frequency Protection

Because of the rapid growth of the power system, there are many new people. In addition, high frequency protection is technically more complicated. In order to ensure the normal operation of high frequency protection, and to improve the operating rate and accuracy rate, we strengthened the control in the following areas.

1. Technical Training

Along with progress made in electronics, more and more new devices are being developed. It is necessary to train both new and experienced personnel. Based on the culture level and work experience, several training methods are used.

(1) Classroom training. This is primary for key relay protection personnel at various power bureaus, power plants, power stations and basic construction units in the grid in order to build a backbone force for the operation and maintenance of high frequency protection.

(2) On-site training. Representatives from manufacturers and research institutes are invited to provide training on-site right by the equipment with regard to testing methods, handling of abnormal situations, and equipment maintenance.

2. Control of Basic Construction

(1) Design review. Design review must be carefully done in basic construction. Measures to prevent incidents must be thoroughly examined to meet operational needs. For example, the design institute and the operating unit must give their consent to issues such as preventing phase selection elements on both sides from being activated one after the other, adding a self-maintained, high frequency protection halt circuit in the phase difference high frequency output, and connecting the high frequency channel to the fault wave recorder, etc.

(2) Absorbing new technology. A basic construction project typically takes a few years to complete from design to construction and production. Certain features might be feasible in the initial design review. However, new "countermeasures" may arise at the time of construction. Equipment ordered may not be able to meet the latest countermeasures. To this end, another design review should be performed during construction. Drawings and equipment must be brought up to date in the form of "design modification note" to meet the new requirements.

3. Management of High Frequency Channel

The high frequency protection system of 220 kV line uses a dedicated transmitter/receiver exclusively for relay protection. The 500 kV line uses a multi-purpose carrier. The following is a brief description on the management of the dedicated high frequency transmission/reception channel.

(1) Choose an operating frequency to meet the protection requirement of the transmitter/receiver. The frequency used for high frequency protection is assigned by the communications department. Because power plants and substations are densely distributed in East China and carrier wave is the main mode of communications, the frequency band is very crowded. In the past, people assigning the frequency did not understand the actual capability of the transmitter/receiver used for protection. Very frequently, it could not meet the protection requirements of the transmitter/receiver due to problems such as the same line did not have the same phase difference or different lines from the same bus but did not have sufficient frequency spacing. It resulted in serious interference and we were forced to stop using it. Or, the assigned frequency was either too high or too low to operate properly. Transistor-based high frequency protection (e.g., JGX-11A, JSF-11A) is suffering from serious oscillation due to self-excitation at very high frequency. The oscillation signal of the transmitter enters the output of the receiver. At very low frequency, the ceramic filter in the reception circuit has a serious trailing effect which makes the current phase lockout angle different from the square wave phase comparison lockout angle. The phase comparison time integral is reduced which leads the system to respond improperly during a fault outside the zone. The operating frequency should be chosen based on the fact that the allowable interference voltage for the dedicated transmitter/receiver is less than or equal to -1.5 N. Its degree of protection must meet the following specifications: 2kC protection $\geq$ 3.3 N for same line different phase, 4kC protection $\geq$ 3.7 N for same line different phase, and 14kC protection $\geq$ 6.1 N for same line same phase.

Transmitter/receiver units designed and manufactured based on the "four in one" principle should satisfy the above requirements. However, the high frequency receiver/transmitter units manufactured by the Acheng Relay Company and Nanjing Automation Equipment Company cannot meet these protection requirements. It is necessary to install frequency dividing filters and differential networks to reduce the channel frequency distribution interval in order to effectively resolve the frequency crowding problem. The frequency dividing filter usually operates in three modes; i.e., high pass/low pass, band pass/band elimination, and differential bridge. Differential network is used more and more because it has a higher power than a frequency divider, it is easier to connect and maintain. A high/low pass filter can be connected with a great deal of flexibility. However, its frequency division is not economical. A band pass/elimination filter can efficiently distribute frequency.

A transmitter/receiver that is exclusively designed based on the "four-in-one" guideline for high frequency protection can be directly connected to the grid. However, a high frequency protection receiver/transmitter must be installed in a different room away from the communication wave carrier. It must be wired with high frequency

cable with a characteristic impedance of 100Ω. Due to a high shunt current loss, the high frequency protection receiver/transmitter cannot be directly wired in parallel. It is necessary to be connected to a single frequency wave eliminator on the high frequency cable side of the communications room to meet the operating requirements.

(2) Assign dedicated management personnel. The equipment used in the shared channel is selected by the communications department. The maintenance of wave eliminators, filters and high frequency cable to the communications room is the responsibility of communication personnel. Frequency dividing filters are installed in the high frequency protection screen and relay protection personnel are responsible for their maintenance.

4. Routine Management of High Frequency Protection

Routine management of high frequency protection is an important step to improve the operating rate and accuracy rate of high frequency protection. Operators should insist on exchanging signals every day or every other day to determine whether the high frequency protection devices and high frequency channel are operating normally according to the operating specifications of different high frequency protection devices. Once defects are found, they must be handled in time. The maintenance time for the high frequency protection systems on both sides must be coordinated. To the extent possible, both sides should be checked out and maintained at the same time in order to increase the on time of high frequency protection.

In summary, the installation of a dual high frequency protection unit can effectively enhance the stability of the power grid and simplify the calculation of the settings for relay protection at different levels. From statistics gathered over several years, the accuracy rate of high frequency protection in the East China power grid is around 90 percent. High frequency protection has cut off faults over 85 percent of the times. Due to the normal operation of high frequency protection, the grid survived many times of natural disasters that covered wide areas. This track record fully illustrated the superiority of a continuously operating high frequency protection system.

Eastern Grid Capacity Update

906B0069C Shanghai JIEFANG RIBAO in Chinese 21 Jan 90 p 1

[Article by Wang Youcheng [3769 1635 2052] and Hu Weiqiang [5170 0251 1730]: "East China Grid Becomes China's Biggest Grid—Installed Generating Capacity Surpasses 20,000 MW"]

[Text] Information released by relevant departments on 20 January 1990 indicates that the installed generating capacity in the East China Grid has now surpassed 20,000 MW, making it China's biggest multi-province grid.

The leap of the East China Grid to become China's largest power grid has major significance for economic development in the east China region in the 1990's. The east China region is the most economically developed area of China and the region having the highest value of output converted from each kWh of power. It was revealed that the East China Grid plans to generate 110.89 kWh of power in 1990, up 6.2 percent from 1989. Plans call for 1 billion kWh of DC power to be transmitted from Gezhouba to Shanghai. In addition, 14 new generators with an installed generating capacity of 2,026 MW including 350 MW at the Huaneng [China Power] Nantong Power Plant, 300 MW at Shidongkou Power Plant, and others will go into operation in 1990. A 300 MW nuclear power generator at Qinshan will also be connected to the grid and generate power in 1990.

Eastern, Central Grids Interlinked

906B0069D Shanghai JIEFANG RIBAO in Chinese 8 Mar 90 p 8

[Article: "East China and Central China Grids Interlinked, 100 Million kWh of Power Transmitted From East to West in 1990"]

[Text] Reporters learned from relevant departments that a 600 MW line, as part of the 500 kV DC power transmission project to link the two big East China and Central China Grids, has gone into commercial operation. In 4 months during 1989, central China transmitted over 570 million kWh of power to east China and during the first 2 months of 1990 the East China Grid for the first time also transmitted over 100 million kWh of power to the Central China Grid. State plans also call for the Central China Grid to transmit 1 billion kWh of power to east China during 1990. The two big East China and Central China Grids must guarantee power supplies needed for industrial and agricultural production and construction in eight provinces and municipalities: Jiangsu, Anhui, Zhejiang, Shanghai, Hunan, Hubei, Henan, and Jiangxi. The Central China Grid depends mainly on hydropower stations, especially Gezhouba Hydropower Station, which has an installed generating capacity of more than 2,700 MW. When hydropower resources are abundant, it can generate 2,800 MW, and some of this power can be transmitted to the East China Grid. Given this situation, the state invested 1 billion yuan to build the first 500 kV DC power transmission line in China. This line can transmit power either from west to east or from east to west. In January and February of 1990, there was little precipitation during the winter, so the Central China Grid had a slight shortage of electric power, whereas the East China Grid had a partial surplus of power. In accordance with the principle of mutual assistance, it supplied power on a daily basis to the Central China Grid starting 1 January 1990. By the end of February 1990, the East China Grid

had transmitted over 114 million kWh of power to central China. Beginning in April, there was an abundant flow rate on the Chang Jiang and hydropower stations were generating power at full capacity, so the Central China Grid supplied power to the East China Grid during this period.

Information indicates that debugging will be completed on another 600 MW line as part of the 500 kV DC power transmission project during 1990 and it will be placed into operation. Projections are that the Central China Grid may transmit 3 billion kWh of power to the East China Grid in 1991.

Construction of Five Power Grids Completed

40130001 Beijing XINHUA Domestic Service in Chinese 0011 GMT 1 Nov 90

[Article by correspondent Li Jumin [2621 5112 3046]]

[Text] Wuhan, 1 November (XINHUA)—According to information provided by the national seminar on large power grids, which ended in Hubei Province's Yichang City recently, China has achieved great success in the construction of large power grids. Today, five large power grids each with a capacity of more than 10 million kilowatts have been completed in the northeastern, northern, central, eastern, and northeastern regions of China. Except for the power grid in the northwestern region, the other four each have a capacity of nearly or over 20 million kilowatts. Through transmission lines stretching directly from Gezhouba to Shanghai, the central and eastern power grids are combined into a joint network spanning the regions. The well-developed distribution networks transmit power through 500,000-volt lines across the nation and 220,000-volt lines within the provinces. China ranks fourth in the world in terms of power generation and transmission.

In order to operate safely and reduce cost, the regional power grids have expedited the process of technical upgrading. The systems for safety and stabilization control as well as automatic control, and a network for special communication have all been set up. During the first nine months of this year, the regional power grids and the provincial control departments were able to ensure stable power supply by optimizing their operating methods and perfecting their control procedures despite the strain on power supply, the difficulties in bridging the wide gap between day and night usage, and natural disasters such as earthquakes, typhoons, and lightning.

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